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Ninety-Eighth Session.

Monday, 21*st February* 1881.

Professor FLEEMING JENKIN, Vice-President,
in the Chair.

The following Communications were read:—

1. Effects of Strain on Electric Conductivity. By M. August Witkowski. Communicated by Sir William Thomson.

2. On the Effect of Moistening with Water the opposed Metallic Surfaces in a Volta-Condenser, and of substituting a Water-Arc for a Metallic-Arc in the Determining Contact. By Sir William Thomson.

3. On Vortex Sponge. By the same.

4. On some Transformations connecting General Determinants with Continuants. By Mr Thomas Muir.

5. Note on the preceding Paper. By Professor Chrystal.

Monday, 7th March 1881.

The Right Hon. LORD MONCREIFF of Tulliebole, LL.D., President of the Society, occupied the Chair, and read the second part of the following Address, the first part having been read on 6th December 1880:—

I.

The subject of the address with which I am to open the present session of the Royal Society has been announced in your notices as the "Dawn of the Constitutional Principle." Such, indeed, was the general tenor or complexion of the thoughts which led me into the field of inquiry on which I intend to dwell to-night, and such the topic round which I propose to weave a very fragmentary and imperfect *excursus* or dissertation. I had long thought that the rise and growth of the constitutional principle in this island,—a plant nurtured in many storms and watered by the best blood of the land,—might be worth tracing in these more stable and peaceful times. It might also be interesting to recall the gradual progress and direction of opinion in the two ends of the island, and of the conflict or concord out of which so powerful and thorough a fabric has been consolidated. But my theme to-night is necessarily less ambitious than its title indicates. I am limited both by the place in which and the audience to which I speak, and also by the time which it would be reasonable for me to occupy.

At present I mean only to say some things about some famous but forgotten political treatises and their authors, not indeed with the intention (as you may well suppose) of entering into any political disquisition on my own part, or of indicating any opinion upon the subjects with which these authors deal. I mean merely to describe the writings and their authors, and draw together as well as I can some particulars respecting both, which, as not being familiar, may prove not uninteresting. Addressing, as I presume I do, men of all shades of political opinion, I shall say nothing that can touch the susceptibilities of any. Tros Tyriusve, Roundhead or Cavalier, Passive Obedience or Fifth Monarchy men, if there are any such among my audience, shall have nothing to complain of, as I mean only to gossip about biography and bibliography, and mainly of the characters and lives of the men whose writings I have taken as my text.

The famous and forgotten treatises to which I refer are substantially five:—1*st*, Buchanan's tract "De jure regni apud Scotos;" 2*d*, Milton's "Defensio pro populo Anglicano" against Salmasius; 3*d*, Samuel Rutherford's dissertation entitled "Lex Rex;" 4*th*, Harrington's "Oceana;" and 5*th*, Algernon Sydney's volume on "Government." These writings were all of them famous in their day. I don't think that I am wrong in saying that they are all thoroughly forgotten now,—so completely forgotten that even the existence of some of them is unfamiliar to most general readers, although the names of their authors are remembered. I doubt if many of my hearers ever read one of them throughout, and most of them I suspect never read a word of any of them.

The two which stand first on my list are the works of very celebrated men—the memory of whom is green and fresh to this day—Buchanan for his prodigious scholarship and his mastery of the Latin language; Milton for a muse which will make him famous to all time, while our language survives. Yet Bayle, in his Dictionary, treats Buchanan's tract as the most renowned of his famous works, and recognises in Milton only the antagonist of Salmasius; nor is it until the later notice in his article under Milton's name, that he condescends even to mention the "Paradise Lost," and then only in reference to a tradition or rumour that Dryden thought well of it. Had the reputation of these two great men rested only on performances which made them the literary heroes of the day, their chance of immortality would have been slight. Brunet, in his "Manuel du Libraire,"—a publication, as is well known, of the present century,—while he fully describes many editions of the works of both, does not guide the collector to a single separate edition of discourses which made such a stir in Europe, and which were separately the subject of more than one continental printing-press. Both Buchanan's treatise and Milton's "Defensio" were printed by the Elzevirs more than once; and yet even these productions of a celebrated press have been apparently forgotten. The other works which I have mentioned have also sunk into utter oblivion, although they also had their share of reputation and influence, and their authors were men of considerable mark; still, forgotten as they are, it is important to remember that they were once famous, and though it may sound like a paradox, the fact of their being forgotten may in some sense be attributed to their power. The ruins of great controversies are almost always worth exploring, although the fabric itself may have perished. These works made their mark, and whether they failed or took effect, they are alike forgotten,—if in failure, because they failed; if in success, because posterity has built on their foundations. These things do more than point the moral of the fleeting nature of popularity. Contemporaneous fame means contemporaneous impression, and if that impression has been deep enough to mould and influence the opinions or the policy of a generation, the next no doubt may wonder at all the trouble bestowed on what seems to them so slight an affair. *Grandiaque effossis mirabitur arma sepulchris.*

More important, however, to the main object of my theme to-night, is the light which such inquiries afford to the student of history. Words which have arrested and absorbed the attention of the public at any given period, are not necessarily possessed of interest at any other. But their celebrity goes far to indicate of what topics people thought, and spoke, and wrote intensely, while that reputation, although ephemeral, lasted. Opinion, social, moral, and political, may be very surely ascertained and tested by the applause accorded to works of contemporaneous controversy. In the present instance the dissertations I have chosen as my theme were the progeny of mighty and convulsing political and social events in both ends of the island. They are strokes of the hammer wielded by vigorous and powerful arms, in times which called for vigour and strength,—times in which the labyrinth of politics could only be safely threaded by the courageous and the wary. Whether my authors found the safest track, or missed their way in devious mazes lost, I shall not try to determine; I only take their words as an index to the times.

The author of the first of these treatises, to which most if not all of my attention to-night must be directed, George Buchanan, was one of the most remarkable men any country in Europe ever produced, and his life was as remarkable as his abilities. Sprung of a humble stock, the son of a farmer in the Lennox, he started on his career with none of the advantages of fortune in his favour. His father having died early, in embarrassed circumstances, he was sent, by the liberality of an uncle, and when only fourteen years of age, to the University of Paris, in the year 1520. He there remained two years, when his kind relative died, and he himself was the victim of a serious illness, aggravated by being left in poverty in a foreign land. He returned home in 1522, when he enlisted as a soldier, and accompanied the Duke of Albany's ill-fated expedition to Berwick in 1523, and thereafter studied under the celebrated John Mair or Major at St Andrews, with whom, after taking a degree as Bachelor of Arts in 1525, he returned to Paris in 1527. After many discouragements and some amount of success, we find him in 1529 as a regent or professor in the College of St Barbe, at the age of twenty-three. The position, however honourable, seems to have been respectable poverty, and one of rather thankless toil; for he thus concludes an elegy, the first of the series in his works, written during his tenure of office, after descanting mournfully on the miseries of a teacher of letters:—

> "Ite igitur, musæ steriles, aliumque ministrum
> Quærite; nos alio sors animusque vocat."

In 1532 he became the preceptor of the young Earl of Cassilis, and after residing with him in France for five years, returned with him to Scotland in 1537, and rose to considerable favour with the king, James V. But his sharp pen and evil fortune brought him into trouble; and having incurred the wrath of the Franciscan clergy by his two satires, still famous, of the "Somnium" and the "Franciscanus," he with difficulty made his escape from prison, and after many adventures returned to France in 1539. Finding himself even in Paris pursued by the enmity of Cardinal Beaton, he accepted the invitation of Andrew Govea, a native of Portugal, and a man of great learning, to fill the office of professor in the College of Guienne, in Bordeaux, in which Govea was principal. There he spent three years in the heart of a cluster of distinguished men, including the elder Scaliger, who resided in the neighbourhood of Bordeaux, and for whom he contracted a warm attachment. While at Bordeaux he wrote his tragedies of "Jephtha" and "Baptistes," mainly as exercises for his students, and among the youthful actors was no less a celebrity than Michel Montaigne. He remembered Buchanan with respect in after years, and names him among the greatest poets of the day. Buchanan returned to Paris in 1544, and was there associated with Turnebus and Muretus in the College of Cardinal le Moine, in that city, and there he seems to have remained with great distinction till 1547, when he was induced to remove with Govea to the University of Coimbra. He was there persecuted by the officers of the Inquisition, who had not forgotten "Franciscanus," and he was ultimately confined to a monastery, where he commenced his renowned translation of the Psalms, which won for him the well-known title conferred by Henry Stephans, "Poetarum hujus sæculi facile princeps." After two years he was released, and ultimately returned to Paris in 1553. Soon afterwards he became attached to the family of the Comte de Brissac, who governed the French dominions in Italy, whither Buchanan accompanied him as tutor to his son, and after five years residence with that nobleman, having been his companion throughout his campaigns, he at last, as serious trouble threatened France, returned to his native country in 1560, after a continuous absence of twenty-one years. He was now fifty-four years of age, having spent more than thirty of them in continental life.

The passage in which Montaigne mentions his remembrance of Buchanan is worth referring to. It does credit to his self-esteem. He is speaking of his proficiency in Latin, and enumerates among his preceptors Buchanan, calling him that great Scottish poet. Of all these he says, "they often told me that I had that language (Latin) in my youth so ready to my hand that they were afraid to address me." He goes on to say, "Buchanan, whom I afterwards saw in the suite of M. le Maréchal de Brissac, told me that he had a design of writing a book on the education of children, and meant to take me as an example." ("Essays," 1–25).

I have thus hastily sketched the career of Buchanan before he again, and finally, set foot in his native land, to be involved in the eddies of the recent Reformation, and the still more exciting troubles of Queen Mary's reign, mainly because I was anxious to outline his previous vicissitudes, and to show what manner of man he was, among what scenes he had been trained, whose words form my theme to-night. When he returned to Scotland, he found that country in the midst of the agitation consequent on the Reformation of 1560. Its political aspect and prospect were troubled in the extreme. In no country in Europe was the *jus regni* more worthy of philosophical, patriotic, and practical thought. From the first of the Stuarts down to the fair and unfortunate princess whose reign was about to commence, misfortune, violence, and treachery had surrounded the Scottish throne. James the First of Scotland, the ablest and wisest of his race, was cut off prematurely by the sword of an assassin. James the Second was killed by the accidental bursting of a cannon. James the Third was murdered by his rebel subjects. James the Fourth fell at Flodden; and James the Fifth died of a broken heart about the time of which we now speak. Although Scotland had the framework—whence derived it is perhaps not easy to say—of constitutional government, it had nothing which deserved the name of constitutional liberty. The people had no voice whatever, and government seemed to consist of a perpetual struggle between the nobility and the crown. When Buchanan returned to Scotland, it was, however, plain that the waters were being stirred. The Reformation had set men thinking, and the free circulation of the Scriptures, and the preaching of the reformed clergy, had given tone and temper to the times. Events rapidly succeeded each other, which in the end threw the kingdom into the convulsions of civil war; but it is not my purpose to trace in any detail that most interesting but melancholy period of the history of this country. A few sentences will bring me abreast of the date of Buchanan's work. I stop for a moment to conclude this chapter of his life by remarking on the singular position held by men of letters in European society in the sixteenth century.

The circles in which Buchanan moved seem to have been very brilliant, very genial, and very poor. Their acquired learning seems to have been prodigious, and considering that the art of printing was not a century old, indicates how intense was the hunger and thirst after knowledge in that generation. Indeed, almost any celebrated work of that time so bristles with learning, culled chiefly from the ancients, but still so minute, and indicating so wide a range, as to fill the modern student's heart with something approaching to despair.

It has no doubt some want of variety, and in some of the controversies to which I have alluded, each combatant bespatters the other with the same kind of arrows drawn from the same quiver, spears belonging to the same armoury; but still their mastery of these weapons is in the last degree admirable. As to how the wise men of those days lived, and what was the tone of their private and social intercourse, it is not easy to form an adequate conjecture. One is apt to fancy that if the Latin language was that of learned conversation—when you complimented your host in Latin elegiacs if he had been civil, and lampooned him in Latin epigram if he had given you offence, the general social atmosphere must have been somewhat pedantic and wanting in ease, as it is certain it was wanting in refinement. Probably, however, this would be an erroneous conclusion, and although without the canons of modern good breeding, it is probable that these circles had brightness, vivacity, and humour. Buchanan is specially mentioned as charming and witty in conversation; and it was said of him that there was not an agreeable man in Europe with whom he was not familiar. In later life he was described by the unfriendly as rustic, "*agrestis*" in his appearance and demeanour, and slovenly in his dress; but age, broken health, and incessant turmoil may have given his bachelor habits, for he was never married, a stronger hold on him than they had when he charmed the fastidious circles of Paris, twenty years before. He had almost ceased to be a Scotchman. The great De Thou claimed him as a countryman—"a native of the banks of the Blane in Scotland, by birth," he says of him, "but one of us by choice." Buchanan probably thought more in Latin and in French than in his mother tongue.

On his first arrival the queen was unquestionably partial to him. He read classics with her, and she confided to him the charge of her son,—for whose benefit indeed the treatise I have spoken of was afterwards composed,—and he dedicated to her the first edition of his Psalms, in an epigram, as he styles it, full of grace. Into the troubles which followed, and the part he took in them—whether he was ungrateful, as one section of critics maintain, or patriotic as the other side says, I do not stop to inquire. He was unquestionably in the front, whatever were the merits of the conflict. But in 1579 the battle was over. His royal pupil was on the throne when he wrote this celebrated treatise. The direct object which

Buchanan had in view was to vindicate the course which the nobility and the parliament had followed in regard to Queen Mary. And when he comes to apply the general views which are announced and enforced in the course of his argument, it is to this conclusion that he wishes to bring his readers. I am not, however, to inquire here how far he succeeds in his main attempt, but I am rather concerned with his work as a philosophical discourse on the principles of government, and whatever opinion one may form of the scope of his performance, there can be but one estimate of its extreme ability, and also looking at him in the light of the times in which we live, of its moderation also. That his ideas on government were to some extent swayed by his own individual experience, perhaps his individual peril, may be assumed. But I think all must see, in this most thoughtful composition, the fruit of long reflection amid many vicissitudes. One peculiarity it has deserving notice; it is a purely political essay. Although he deals with the power of the pope and the Roman Catholic clergy, the views illustrated are hardly tinged at all with the ecclesiastical controversies of the time, and indeed Buchanan was little of an ecclesiastic, although he and Knox appear to have been intimate. The sketch which he gives of his ideal ruler is worked out in Latinity of wonderful elegance and power, with a subtle continuity of reasoning which marks the weight and depth of a true statesman.

The treatise itself is cast in the form of a dialogue between Buchanan and a friend—Thomas Maitland—a brother of Maitland of Thirlstane, himself a man of letters of some repute. This machinery of dialogue gives, especially at the outset, an impression of restraint and weariness to the reader, and excites a wish that the author would come to the point much sooner. Indeed, he takes the lion's share of the conversation to himself, and his friend can hardly have been flattered by the interjectional and fractional utterances assigned to him as his contribution to the discourse. But there was an ingenious design in this. This supposed listener, or disputer, is used to modify, qualify, and illustrate Buchanan's own propositions, to wear off their edges and prevent them being too bluntly and ungraciously presented. Maetellanus, or Maitland, has a leaning for monarchy, and a fear of the many-headed monster, without carrying these to excess: he likes "the divinity that doth hedge a king," and the pomp and circumstance of royalty; and Buchanan, while maintaining his own view, is pleased to grant great weight and some sympathy to that of his friend. He starts with the propositions—not new in these days, but in those audacious and dangerous—that all government exists for the people and from the people, and lays this down as a fundamental axiom, admitting of no controversy. His friend does not directly assent to the principle, or impugn it; but he says "Oh, I understand you. You are one of those who like republics, like Venice or Rome, or the Massilians." "No," rejoins Buchanan, "you do me great injustice; that is not my opinion. It is not the form of government in these states which I think commendable, but the equity of their institutions. The doge of Venice is as much a king as any other, and we need not quarrel about names." He goes on, perhaps a little tediously, and interrupted by brief sounds of assent from his friend, to illustrate these principles. He takes the analogy of a physician, who must know the laws of nature before he can apply them; and of science and the arts, which must be studied and mastered before they are successfully reduced to practice, and maintains that government is an art. He recurs frequently to both these illustrations, and it is amusing to surmise that from the last his royal pupil, who did not carry out his preceptor's lessons otherwise, probably derived that idea of kingcraft of which he considered himself so great a master. He goes on to consider the just place of constitutional law, and the authority of parliaments in their relation to kingly authority, holding the monarch not to be above the law, but yet with a power of tempering by his royal prerogative, the necessary inequalities of its letter. He then proceeds to point out how much a monarch's personal observance of law tends to encourage the obedience and good order of his subjects. This part of his theme he winds up with the most striking passage of the treatise, a passage of splendid Latinity, and of the truest and highest eloquence. His friend sneers, or is made to sneer, at the constitutional safeguards with which he surrounds his monarch. Buchanan, in reply, draws a picture of his ideal ruler. He breaks out into an impassioned description of a patriot king. "Can any honour, dignity, might, or majesty be described or be conceived in any man greater than to be able by speech, intercourse, reputation, aspect, and the tacit influence of example, to bring back the dissolute to moderation, the violent to justice, the senseless to reason?" "Do I now," he exclaims, "appear to think meanly of your king? Do I represent him as loaded with chains and confined in a prison house of laws? Do I not bring him out into the theatre of the human race?" The rest is conceived and expressed with such spirit that I give it in Buchanan's own words: "Non superbo spiculatorum coetu, sericatisque nebulonibus stipatum, sed sua tutum innocentia, nec armorum terrore, sed populi amore, munitum; nec modo liberum et erectum, sed honoratum, sed venerabilem, sacrosanctum, et augustum; cum bonis ominibus et faustis acclamationibus prodeuntem, et quocunque progrediatur, omnium ora, et oculos, et animos in se convertentem." "Not surrounded by a proud escort of javelin men, or an imposing band of knaves, but secure in his own innocence; guarded not by the terror of arms, but by the love of his people; not only free and erect, but honoured, venerable, sacred, and august; going forth with all good omens, and happy acclamations, and, wherever his steps are directed, turning all faces, and eyes, and hearts towards him." This noble passage quite melts the heart of his friend Maitland, who assures him that nothing more magnificent could be conceived. This was his ideal in 1580. In 1880, I think we may say that Buchanan only lived before his time, and that the ideal has changed into reality.

Buchanan has some views on the powers of parliament, and the obligation of laws passed by them, which would hardly find acceptance in the present day, and which were sharply canvassed at the time. He had a notion that the tacit assent of the people was necessary to give efficacy to the laws passed by parliament; from which it would follow that at the time the law was passed it was not binding. But we must remember this was but the dawn of Constitutionalism.

If Buchanan hoped to raise his immediate reputation by this masterly performance, he must have been greatly disappointed. He died in 1582, and before his history was in the hands of the public. But he was assailed from all quarters, abroad and at home. Every calumny that malignity could suggest was levelled at his private character. He had been a Franciscan friar, they said, and therefore was a renegade. He was in private life one of the vilest of men. His book was a scandal to his race. The Scottish Parliament in 1584, two years after Buchanan's death, condemned it and his history to be burned by the common hangman. He was met by numberless replies, the most pungent of which was written by Barclay, the father of the author of the "Argenis." Even the Protestant party on the Continent began to speak of him as a man of no consequence, as they did not wish their religious opinions to be mixed up with questions on government. They said he had recanted on his deathbed, and this was kept up for a century, and I suppose lives still, as a controversy which cannot be settled. "Nevertheless," says Bayle, in his caustic vein, "Buchanan's 'Dialogue' made a great noise; and some of those who most strongly condemned him were found quoting maxims from it before five years were over."

It may be questioned whether the times were ripe for such views, and indeed there is no question at all that the first effect of the publication was to delay the advent of constitutional liberty. But the courage of the man who thus openly proclaimed them cannot be denied; and in this respect, perhaps, he is entitled to stand on a higher level than some of the authors to whom I mean now to proceed.

On the whole, as Bayle says, he cannot be denied the praise of an elegant genius and an admirable style. For myself, I think his intellectual power was immense, but that a vein of harshness and hardness ran through his powerful character, which was more strongly developed in his later years. He had imagination and taste, but little sentiment; a strong sense of duty, but too little flexibility for a successful politician. I end these cursory remarks with quoting Thuanus' (or De Thou's) character of him, a tribute from such a quarter being quite sufficient to attest his contemporaneous reputation and his real merit.

Thuanus says, in book lxxvi. of his "History," at page 415 *:—"Ante eum Georgius Buchanan, 4 Kal. Oct. exacta Aetate, et 76 annum supergressus, decesserat, vir ingenii felicitate, et scribendi facultate, quod ejus scripta ad omnem eternitatem victura vel fatente invidia, testantur, nostra aetate incomparabilis." After giving a short sketch of his life, and claiming him, as I have said, for a countryman, he thus concludes:—"in senili otio patriam historiam aggressus est; quam tanta puritate, prudentia et acumine

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* Edition, Francofurti, M.DC.XXV.

scripsit, quamvis interdum libertate genti innata contra regium fastigium acerbior, ut ea scriptio non hominem in pulvere literario versatum, sed in media hominum luce, et in tractandis reipublicæ negotiis tota vita exercitatum redoleat."

II.

I propose to-night, with the leave of the Society, to conclude the paper the first part of which I submitted to them on a former occasion. My theme, as I expressed it, was to consider some famous and forgotten treatises on government and their authors, with the view of elucidating the rise, nurture, and maturing of the constitutional principle in this island. I confined myself in that paper to the consideration of Buchanan's treatise "De jure Regni apud Scotos," along with some passages in the career of that remarkable man. I now part from him and his period and, stepping over half a century, come to the eventful year of 1644.

The interval, however, counts for a great deal in the political education of this country. In Buchanan's time, constitutional liberty was little known in our end of the island. We had our nominal representation in parliament, but as far as any real popular control was concerned, it was little but a name. What with intrigue, political faction, and family feuds, the phantom of representative government flitted round the Parliament House, but the real principle of power resided in the favourites and satellites of the palace. I showed in my last paper that Buchanan, although bold and outspoken, was by no means anti-monarchical, although deducing, as all constitutional writers have done since his time, the regal power from the popular will. But, considering the temper of the times, and the arbitrary tone of the Scottish monarchs, it is creditable to Buchanan's courage, as well as to his foresight, that he did not hesitate to proclaim the distasteful doctrine in ears to which he knew its sound would be unpalatable.

As it was, however, and as often happens, the force and earnestness with which the preceptor of James VI. had laboured to bend this stubborn and ungainly royal branch, proved to have inclined it strongly in another direction. Of his preceptor's learning, James VI. had imbibed a considerable share. His own intellect, although not lofty, was acute and sagacious; and the kingcraft he had learned at the feet of Buchanan, he applied to an end very remote from that intended by his instructor. If the Scottish monarchs of old were less fettered by the restraints of constitutional law and parliamentary privilege than their brothers in England, the latter had one advantage, of which James, when in 1603 he took possession of his new dominions, was not slow to avail himself. The king of England was a far more remote and inaccessible potentate than his royal brother of Scotland. The latter was never secure from being invaded, scolded, and rebuked by some faithful counsellor, at any hour of any day. Thus his ordinary life was superintended and criticised by his subjects, and his plans and projects were discussed with a freedom which the regal state of Whitehall rendered impossible. James, with the Tweed safely between him and his loving Scots, breathed freely, and matured gradually but effectively, in private and unmolested, those visions of kingly power which had been the fruit of the lessons of his ardent master.

Very slowly, but very deliberately and skilfully, did the king develop his policy. To diminish the power of parliament in one end of the island, and that of the Presbyterian party in the other, was the instrument by which he hoped to make the British throne the seat of a true king—not such a monarch as Buchanan's ideal of a patriot king presented, but an embodiment of that divine essence of royalty which could place him alongside the arbitrary models on the Continent. Such was his ambition, and had he not died prematurely it is possible he might have succeeded. He went to work so cautiously that he excited no public, and hardly any private, discontent. He temporised, he flattered, he threatened, but never struck until he was certain he could do so safely. The invisible threads of the royal cobweb stretched across and across the island without the nation perceiving, from one day to the next, how far they had gone on their way to despotism, or how much more dim and distant were their liberties.

But the fabric perished at his death. The unpractised and clumsier hand of his son tore away the slender filaments, and in 1644 the contest between the king and the parliament was at its height.

I turn from the projects of kings to a treatise by a man whose name is not now trumpeted by general fame; but, nevertheless, that of one who in his day contributed not a little to the historical events of that time. His name is well remembered in the cottage population of our land, but is probably chiefly familiar to the general reader by the scornful lines of one greater than he:—

"Dare ye for this renounce the civil sword
To force our consciences which Christ set free,
And side us with a classic hierarchy,
Taught ye by mere A. S. and Rutherford."

So wrote John Milton, in the height of a controversy in which he was destined to be worsted in the end, but which still casts its lengthened shadow over our civil institutions.

While the Westminster Assembly of Divines was still in the midst of its labours, a book was published by one of its members, entitled "Lex Rex"; or, the Law and the Prince. It made a great noise at the time. The author was Samuel Rutherford, a Scottish divine of great ability, who was one of the delegates sent to the Assembly by the Presbyterians of the north. He was of humble birth, but his career in such learning as the University of Edinburgh could at that time afford, was so rapid that, at the age of twenty-three, he was elected one of the regents of the college. He afterwards became minister of the parish of Anwoth. Having written an ecclesiastical treatise which gave offence to the authorities, he was for some time imprisoned in Aberdeen, and during his confinement he wrote a volume of letters, which is still a very popular book with the lower orders in Scotland. His talents having marked him out as one of the foremost among the Scottish divines, he was sent by the Scottish Assembly to that of Westminster in 1643, along with Henderson, Gillespie, and others. He took a leading part in its proceedings, and especially in the controversy between the Presbyterians and the Independents, to which he contributed a publication which earned for him the sarcastic lines I have quoted.

It may be as well, however, before I draw attention to this work, to look for a moment at the surrounding circumstances in which it was composed, which were not without a material influence on the opinions expressed in it. For this purpose I would withdraw your attention for a moment from the author and his work, and fix it on the position of the Westminster Assembly in 1644, as graphically described in Baillie's "Letters."

These letters of Baillie, apart from the object for which I refer to them now, are a perfect mine of historical anecdote at a very critical time. Baillie was Principal of the University of Glasgow; he wrote well, and was apparently a great correspondent. These, his familiar letters, contain many amusing descriptions of the impressions made on him by English institutions and manners. I stumbled on a passage of some interest in the present day. He says, writing in 1644, "The heat and clamorous confusion of the Assembly is ofttimes greater than with us,—the reason I think is their way both in Assembly and Parliament, to divest the speaker and prolocutor of all authority, and turn them into a very and mere CHAIR, as they call them," an inconvenience which it seems two centuries and a half have not altogether removed. In another place he says that he finds the English a strange people, in wishing to be different from any other nation. In the midst of their labours on the Confession and the Catechism, the great grievance of the dominant Presbyterian party, was the pretensions of the Independents. They wanted, forsooth, to be tolerated, a thing not to be thought of. It is in his capacity of a champion of that party that Cromwell first appears on the scene, and greatly does he trouble the worthy Principal's repose. He cannot disguise from himself, and his correspondents, that he is an able man. "The man," he says "is a very wise and active head, universally well beloved as religious and stout"—but he cannot forgive him his independency. He grudges him every battle he wins for the parliament. At the battle of Naseby, he recounts with undisguised glee that Prince Rupert made "the Independent Colonels Pickering and Montague flee like men," as he expresses it; and while he tells with some triumph of Cromwell's victory, he cannot resist the reflection—"Some fears the insolence of others, to whom alone the Lord has given the victory of that day." It is plain that even then Cromwell had distinctly indicated his own democratic views. Speaking of the misunderstanding between the Earl of Manchester and Cromwell, which occurred about this time, Baillie says, "Always my Lord of Manchester has cleared himself in the Lords, and hath recriminate Cromwell as one who has avowed his desire to abolish the nobility of England, and has threatened to make a party of sectaries, to extort by force, both from King and Parliament, what conditions they thought meet."

So stood, during the lifetime of Charles, the controversy between the Presbyterians and the Independents in the English parliament, when the treatise of which I now speak was written.

It was first printed in 1644. It is written in good, nervous, vernacular English, and is evidently the work of a man of learning and culture. Bishop Burnet sneers at the attainments of the Scots delegates Henderson, Rutherford, and Gillespie, but there is no doubt they were men of mark in an assembly which boasted Selden as one of their number. This treatise is full of traces of extensive erudition; somewhat overlaid with quotation and example from ancient authority, as the fashion of the time was; but the style is clear and manly, and the continuity of the reasoning well sustained. The author, although without much acknowledgment, follows the line of Buchanan, as the next and more famous treatise follows largely the illustrations of Rutherford. The work professes to be a reply to a pamphlet by Maxwell, the deposed Bishop of Ross, in which he undertakes to establish the divine right of kings, and the unlawfulness of resistance on the part of the people. Maxwell entitles it "Sacro-sancta Regum Majestas." I of course do not mean to follow Rutherford through his demonstration. My main object is to show, that in proving that law is king, the author had in view throughout the true constitutional principle, as we now understand it, and gives his vote, with no uncertain sound, for King, Lords, and Commons. One or two quotations from his work will place this beyond question. He says in one passage, "Power and absolute monarchy is tyranny, unmixed democracy is confusion, untempered aristocracy is factious dominion." And when he comes to consider the question which he propounds "Whether monarchy be the best of governments," he thus resolves it—

"Nothing more unwillingly do I write than one word of this question. It is a dark way; circumstances in fallen nature make things to be *hic et nunc* evil, though it appears to me probable that monarchy in itself, monarchy *de jure*, that is, lawful and limited monarchy, is best even now, if other circumstances be considered." Then, after illustrating various views of this proposition, he thus sums up:—"Every government hath something wherein it is best. Monarchy is honourable and glorious-like before men; aristocracy for counsel is safest; democracy for liberty, and possibly for riches and gain, is best." "A limited and mixed monarchy, such as is in England and Scotland, seems to me the best government, when parliaments, with the king, have the good of all the three. The government hath glory, order, unity, from a monarch; from the government of the wisest it hath safety of counsel, stability, and strength; from the influence of the commons it hath liberty, privileges, promptitude of obedience."

These quiet, well chosen, moderate words contain the first enunciation, as far as I know, in the English language, of the true estimate of the British Constitution. Written as it was, when the king of England was at war with the parliament, the clear good sense of the Scottish divine brushed away the numberless fallacies by which the daily round of political life was then beset, and moved neither by divine right, or theocracy, or republicanism, announced in these unfaltering words the doctrine which was to raise Britain among the nations.

What part the early dawnings of Cromwell's ambition played in inciting Rutherford to this demonstration, we can hardly tell; but so it is that while Scotland sounded the first note of resistance, she never was republican. Rutherford's book, like Buchanan's, was, after the Restoration, condemned to be burnt by the hands of the common hangman; and he himself only escaped punishment by his supervening death.

Of the work itself, Bishop Guthrie says, that "every member of the Westminster Assembly had in his hand that book lately published by Mr Samuel Rutherford, which was so idolised that whereas Buchanan's treatise 'De Jure Regni apud Scotos' was looked upon as an oracle, this coming forth, it (Buchanan's) was slighted as not anti-monarchical enough, and Rutherford's 'Lex Rex' only thought authentic."

In regard to the views of the Scotch Presbyterians and the English Independents, it has been too little considered that these different schools of thought arose from different roots. The Presbyterian opinions were those of the successful Reformers, the Independents reflected those of the persecuted Puritans. There was no tinge of republicanism in the polity of Knox, while the oppressions of Elizabeth in England were never forgotten.

But subsequent events, and the progress of opinion, soon threw Rutherford's simple and manly tenets into the shade. Five years afterwards came the trial and death of the king, an event which shook European society to its centre, and threw round the principle of absolute monarchy a tinge of romance and sentiment not yet extinct. True to the principles of monarchy, and by no means sympathising with the more advanced opinions of the Independent party, Scotland, on the king's death, had proclaimed Charles II. But in England the Commonwealth arose on the ruins of the monarchy, and the absolutist and republican elements confronted each other in a war of words which rang throughout Europe. In the midst of the excitement and consternation which the proceedings of the English parliament had produced, two champions stepped into the lists who drew the eyes of all onlookers. One was a Frenchman of the name of Saumaise, or Salmasius, according to his Latinised patronymic; the other was John Milton, Cromwell's secretary, and the author of the "Paradise Lost."

Jean Saumaise was a professor at Leyden, and was attached to the court of Queen Christina of Sweden. He had the reputation of being the most learned man in Europe; and notwithstanding the frantic personalities of the controversy which ensued, undoubtedly deserved his fame. He was originally a barrister, but ultimately pursued the avocation of a grammarian and schoolmaster. In 1749 and 1750 he was in great repute, and Charles II., when a fugitive abroad, retained him to write a treatise in defence of the late king, and gave him a *honorarium*—I suppose a considerable sum in those days—of a hundred Jacobuses.

This famous work was published in 1649, the year of the king's death. It is entitled, "Defensio Regia pro Carolo Primo, ad Serenissimum Magnæ Britanniæ Regem Carolum Secundum, Filium natu majorem, Heredem et Successorem legitimum. Sumptibus Regiis." Such is the title page. I quote the title page for a reason which will immediately appear.

I have no intention of travelling through this bulky, but with us, at least, forgotten volume. The tenets which it advocates are those of the highest supporters of the doctrine of divine right, enforced by the same arguments, analogies, and illustrations as those to which Buchanan replied, and almost, in some instances, in the very words which Father Maxwell, Rutherford's opponent, had used. But Salmasius in two respects earned the greater and almost solitary celebrity which his work attained. In the first place, it cannot be denied the praise of flowing and elegant Latinity, and a lively vivacity of style. Hobbes of Malmesbury said of it and of Milton's reply, that it was hard to determine which of them wrote best, or reasoned worst. It is worthy of a great scholar, and indicates a keen penetrating judgment. It is, of course, the work of an advocate, evincing no knowledge whatever of the true science of government, but the advocate is clever and not undignified. But doubtless the book would never have commanded the attention, or produced the excitement which followed it, apart from the startling and tragical circumstances which called it forth.

It is far from the province of this paper, and would be entirely out of place, if I were to enter or express any opinion on that remarkable event. Scotland was no party to it. Looking back from our present point of view, there is probably little difference of opinion on its political and moral character. At the time it produced a shock in every court, or political circle, or intelligent community in Europe, such as no public event had ever caused previously. From treating a king as a divine vicegerent, and treating him as a culprit at the bar of his subjects, there was of course a wide chasm. But this bold and audacious proceeding startled and shocked even the advanced statesmen of that day, and gave to sentiments and opinions, which might have passed for platitudes or extravagance, an importance and acceptance they could not otherwise have commanded. Carlyle, in his own singular but expressive language, expresses the general effect on society. "It did in effect," he says in his "Letters and Speeches of Cromwell," "strike a damp into the heart of Flunkeydom throughout the universe." Hence the indignant periods of Salmasius, couched in the elegant language of learning, at that period created an immense sensation, and, as may be supposed, in England, then under the Commonwealth, no little resentment.

Milton, who at that time was acting as Cromwell's Latin secretary, was selected to prepare a reply. He performed his task, although delayed, as he himself explains, by the state of his health; and in 1651 he published his "Defensio pro populo Anglicano," in reply to Salmasius. Whatever were the intrinsic merits of his work, or whatever the temper of the times in 1649, when the tragedy was recent, two years had elapsed, and Milton's essay was by universal consent admitted to have the best of it. Bayle says of it that it made Milton spoken of throughout the whole world by everyone. Europe was probably unconvinced, but it was amused. It laughed, if it did not assent. Queen Christina herself joined in the general enjoyment of the pungent and effective retort, and looked coldly on her discomfited protegé. The book is now unread and forgotten, but, as I pointed out the other evening, Bayle in his "Dictionary" mentions Milton as the opponent of Salmasius, as if that were his chief and almost his only title to a place in his work.

Nevertheless, had we been to pronounce judgment now on this celebrated tract, putting aside the political views maintained and defended in it, I am not sure that our verdict would be the same. In point of reasoning on the principles of government it follows the lines, up to a certain point, of Buchanan and Rutherford, borrowing largely from both. In this part of the subject there is nothing in his views which would ever have acquired for him the celebrity which followed him. The real characteristic of the treatise, such as it is, consists in the hearty, unrestrained, and amusing abuse which the author, from beginning to end, showers on his antagonist and his book, and the diverting use which he makes of the sonorous and dignified language in which his thoughts are clothed, as the vehicle for an unremitting volley of gibes, sarcasms, grim jokes, and even puns, at the author's expense.

One or two specimens of his style will serve to illustrate this estimate, and place both the majestic poet and the powers of the Latin language in a novel point of view. I quote, for the most part, Walsingham's translation.

In his preface he starts with the strain which he sustains, with unabated spirit, to the end. After quoting the title of his enemy's book, which I have read, he says:—"You undertake a wonderful piece of work, whoever you are, to plead the father's cause before his own son; a hundred to one but you carry it. But I summon you, Salmasius, who heretofore skulked under a wrong name, and now go by no name at all, to appear before another tribunal, and before other judges, when perhaps you may not hear those little applauses which you use to be so fond of in your own school." Then, going to the foot of the title-page, he finds "*Sumptibus Regiis*," on which he goes off:—"At the king's charge. O mercenary and chargeable advocate! Could you not afford to write a defence for Charles the father, whom you pretend to be the best of kings, to Charles the son, the most indigent of all kings, but it must be at the poor king's charge? But though you are a knave, you would not make yourself ridiculous in calling it the king's defence; for you having sold it, it is no longer yours, but the king's indeed; who bought it at the price of a hundred Jacobuses—a great sum for a poor king to disburse. I know very well what I say, and it is well known enough who brought the gold, and the purse wrought with beads. We know who saw you stretch out greedy fists under pretence of embracing the king's chaplain who brought the present; but, indeed, to embrace the present itself, and by accepting it, to exhaust almost the king's treasury."

"But now the man comes himself—the door creaks—the actor comes on the stage."

In this strain of personality, badinage, and abuse, he continues to the end; not dignified certainly, but the Latin dress takes somewhat off its scurrility. He has one or two stock subjects of allusion. One is that Salmasius has a termagant wife. In Salmasius' work he quotes, as Father Maxwell had quoted, the example of the lower animals in favour of absolute monarchy:—"The bees have a king over them, the bees of Trent you mean; do you remember? All other bees you yourself confess to be Commonwealths." "But leave off playing the fool with bees—they belong to the muses, and, you see, confute such a beetle as you are." "Now you begin to be personally concerned. 'Gallus Gallinaceus,' you say, 'has both cocks and hens under him.' How can that be? since you who yourself are Gallus" (a Frenchman) "by report cannot govern your own single hen, but let her govern you." Again:—"I will throw you a great many barleycorns, if in ransacking this dunghill book of yours you can show me but one jewel. But why should I promise you barley, that never pecked at corn, as that honest plain cock that we read of in Æsop, but at gold, as that roguey cock in Plautus, though with a different event, for you found a hundred Jacobuses, and he was struck dead with Euclid's club, which you deserve more than he did."

These hundred Jacobuses crop up perpetually. Salmasius says, "Betwixt the two extremes of kingly power there are three more temperate species interposed, as there lie three zones betwixt the torrid and the frigid." "Pretty rogue!" says Milton, "what ingenious comparisons he always makes us; may you for ever be banished whither you condemn an absolute kingdom to be, that is to the frigid zone, which, when you are there, will be doubly cold." And so he discusses these zones to the end of the chapter, which he ends thus:—"You deny that there was any light in Moses' heaven before the sun; and in Aristotle's you make three temperate zones. How many zones you observed in that golden and silken heaven of the king's I know not, but I know you got one zone (punning on the Latin word)—a purse—well-tempered by a hundred golden stars, by your astronomy."

It is difficult in translation to give the full effect of these gibes as they appear in the Latin version, although Walsingham's rendering is very faithful and spirited; what I have given may serve as a specimen. The book is full of them; some more humorous, but less decorous; and, in short, it is the last book one would have supposed to have been written by the author of the "Paradise Lost." Of course, by what I have said, it may be inferred Milton is not satisfied with refuting the theory of divine right, but justifies the action of the nation in abolishing, not the monarchy only, but the House of Lords also. But had he foreseen that his book would not be many years in print before the government of this country would be more absolutely in the hands of one man, and that man his own master, than it ever was in those of the monarchs he condemns, it might somewhat have tempered the profound admiration he expresses for the great, and, as he thought, permanent work which he attributes to the English people.

One other passage he has worth my alluding to. Salmasius says that "the Presbyterians may justly challenge the glory of its beginning and progress" (referring to the execution of the king). "Hark! ye Presbyterians," says Milton, "what good has it done you? How is your innocence and loyalty the more cleared by your seeming so much to abhor the putting of the king to death? You yourselves, in the opinion of this everlasting talkative advocate of the king, your accuser, went more than half-way towards it. Woe be to you, in the first place, if ever Charles or his posterity recover the crown of England; assure yourselves you are like to be placed in the black list." He was not far wrong; but our friend Principal Baillie retained till the Restoration his ancient grudge against the Independents, and all their doings. He welcomes Charles II., in 1661, in words in which we hardly recognise the original. "The king, in moderation, wisdom, piety, and grave carriage, giving huge satisfaction to all," and takes his last leave of the Independents and our author, with this rather malignant chuckle, "It was but the justice of God, to disgrace the two Goodwins, blind Milton, Owen, Norris, and others of that maleficient crew."

I need not follow the fate of this controversy or the combatants farther. The dispute did not stop there; nor was the event fortunate for either. Milton lost his sight shortly afterwards in some measure from his labours in this cause. Salmasius lost both reputation and favour, and died within two years. The war of words was carried on, and Milton had to make another rejoinder to more ignoble antagonists, until the conflict degenerated into the lowest personal abuse.

As an example of Milton's power over the language he wielded, his "Defensio" is worthy of the highest praise. It is not the composition of a man who thought in Latin, as Buchanan did; and possibly Salmasius, who writes gravely, was more severely classical. But Milton's power of Latin expression, for ease and ductility, is something wonderful, and proves a familiarity with all moods of the language which few have ever excelled.*

The following anecdote, which I take from Todd's preface to Milton's works, is worthy the attention of scholars. Ellwood, the quaker, acted as his reader after his blindness, and says:—"At my first sitting to him, observing that I used the English pronunciation, he told me if I would have the benefit of the Latin tongue, not only to understand and read Latin authors, but to converse with foreigners, abroad or at home, I must have the foreign pronunciation," and accordingly Milton proceeded to teach him what I fancy our old High School masters taught us—a striking testimony from so great a master of the language.

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* "The Swedish ambassador again complained of delay in his business, and that when he had desired to have the articles of this treaty put into Latin according to the custom for treaties, that it was fourteen days they made him stay for that translation, and sent it to one Mr Milton, to put them into Latin." (Whitelocke, p. 645, "Minutes of the House of Commons.")

Altogether this treatise, of which I now take my leave, does not rise to the height of the great argument, clever and entertaining as it is. One or two noble sentiments in praise of liberty are to be found scattered up and down its pages; and its power is undeniable, in its own style, but it is captious and hypercritical. Butler, who was a strong royalist, was not without reason when he wrote:—

> "Some polemics use to draw their swords
> Against the language only, and the words,
> As he who fought at barriers with Salmasius,
> Engaged with nothing but his style and phrases,
> Waived to assert the murder of a prince,
> The author of false Latin to convince."

Fortunately Milton's mighty name rests on a more enduring and firmer pedestal. Yet in this work we may see combined his love for those two companions of whom he says:—

> "In thy right hand lead with thee
> The mountain nymph, sweet Liberty,
> And if I give thee honour due,
> Mirth, admit me of thy crew."

I must, however, try to draw this essay to a conclusion. There were published about this time two other political treatises of some celebrity—the first Hobbes's "Leviathan," and the second, Harrington's political romance, entitled "Oceana." But I do not stop to analyze them, because their views are too fanciful for practical affairs. Hobbes would have none of the democratic element. Democracy, he maintained, had not even the merit of being the government of the many, but was merely the government of half-a-dozen orators. Harrington, on the other hand, is all for a Commonwealth; and he sketches in considerable detail, and with great ingenuity and acuteness, his ideal constitution for "Oceana." One peculiarity of it was that the elections were to be taken by ballot. His book was published during the Protectorate, and dedicated to Cromwell. But I pass on to the last on my list, Algernon Sydney's "Treatise on Government," and a few words on that work will bring my remarks to a close.

Algernon Sydney, the second son of the Earl of Leicester, as we all know, was one of the last victims of political oppression before the Revolution. He was convicted of accession to the Ryehouse plot, and executed in 1683. He had been a strong opponent of Cromwell's tyranny, and whatever his complicity in the alleged plot may have been, there can be no doubt of the iniquity of his trial and sentence, which was solemnly reversed by parliament after the Revolution. But my only concern at present is with his contribution to the constitutional idea or principle.

The discourses on government were not published until five years after Sydney's death. They were written in opposition to the views of a royalist writer, Sir R. Filmer, a defender of absolute monarchy, and of the doctrine that kings are above the law. Sir R. Filmer's tracts were published anonymously in 1652, and this series of discourses by Algernon Sydney probably was written some years afterwards. It shows a great advance towards maturity in the thoughts and opinions of men on these important topics. The collision of published thought, and still more the irresistible logic of events, had done much to dispel many visionary and enthusiastic tenets. The country had seen the doctrine of divine right develop into general revolt. They had seen the republican spirit of the Independents develop, by a rapid transition, into military despotism of the most arbitrary kind. It was time to profit by the lessons of experience, and to fall back on less excited and more moderate counsels. This work of Algernon Sydney is a philosophical, thoughtful, practical work. Take it altogether, it is the best of the series; and, while it combats with great learning and power the dogmas of Sir R. Filmer, breathes a tone of reflective moderation which contrasts strongly with the subacute excitement which pervades the others.

The exhaustive table of contents which is prefixed to his volume, containing the heads of his discourse, furnishes a very clear analysis of the principles contained in it. I extract one or two of them, which indicate the colour of the whole.

Chap. ii., Sec. 16. The best governments in the world have been composed of monarchy, aristocracy, and democracy.

Chap. ii., Sec. 28. Men living under popular or mixed governments are more careful of the public good than in absolute monarchies.

Chap. ii., Sec. 30. A monarchy cannot be well regulated, unless the powers of the monarch are limited by law.

Chap. iii., Sec. 37. The English government was not ill constituted; the defects more lately observed proceeding from the change of manners, and the corruption of the times.

On the form of government he says under the first head:—

"As for democracy, I believe it can only suit with the convenience of a small town, accompanied by such circumstances as are seldom found. But this no way obliges men to run into the other extreme, inasmuch as the variety of forms between mere democracy and absolute monarchy is almost infinite; and if I should undertake to say there never was a good government in the world that did not consist of the three simple species of monarchy, aristocracy, and democracy, I think I might make it good."

"On the other side, in a popular or mixed government every man is concerned; every one has a part, according to his quality or merit. All changes are prejudicial to all; whatsoever any man conceives to be for the public good, he may propose it in the magistracy, or to the magistrate; the body of the people is the public defence; the advantages of good success are communicated to all, and every one bears a part in the losses. This makes men generous and industrious, and fills them with love to their country."

This is well thought and expressed. One quotation more on the English constitution will end this paper.

"Our ancestors may evidently appear not only to have intended well, but to have taken a right course to accomplish what they intended. Taking our affairs at the worst, we shall soon find that if we have the same spirit they had, we may easily restore our nation to its ancient liberty, dignity, and happiness, and if we do not, the fault is owing to ourselves, and not to any want of virtue and wisdom in them."

These words have the true ring. They were published in 1688, and the experience of two centuries of great prosperity has confirmed their sagacity.

The following Communications were read :—

2. On the Intrinsic Muscles of the Mammalian Foot. By Dr D. J. Cunningham.

3. On the Expansion of Rational Fractions, &c. By Mr A. H. Anglin.

4. Algebra of Relationship. Part III. By A. Macfarlane, M.A., D.Sc., F.R.S.E.

§ 1. In my previous papers on this subject* I used the relationship terms, not in a representative but in a class sense; for instance, cA was employed to denote the children of the man A, and U was employed to denote the total assemblage of mankind, or a limited portion of that assemblage. I have found it useful for the purpose on hand to analyse these symbols into their component elements. Let U denote a man representatively, that is, *any man*, then mankind is appropriately represented by ΣU, where Σ has its ordinary mathematical meaning of taking the sum. Also U_A is the appropriate mathematical expression for the man who has the name A, and A standing by itself is to be regarded as a contraction for U_A. This notation is useful where, as in the present case, the universe of the investigation is composed of individuals; but since the universe may be continuous in its nature, by taking U to denote *the whole*, a more general basis is given to the Algebra of Logic, and accordingly I adopted that notation in my work on the subject.

§ 2. Similarly, let c denote *child* in its representative sense, then ΣcA denotes all the children of A; and with the aid of the numerical and certain other symbols we can express one, two, three, &c., children of A; or the only, the two, the three, &c. (as the case may be), children of A; or the first, the second, &c., child of A.

First. $1cA$, $2cA$, $3cA$, &c., may be used to denote a certain child of A, two children of A, three children of A, and so on. These may be called *partial or indefinite* numbers, as the first corresponds to the indefinite article.

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* Proc. Roy. Soc. Edinb., vol. x. p. 224, and vol. xi. p. 5.

Second. A dot placed over a number may be used to express that it is the complete number; as $\dot{1}cA$ the only child of A, $\dot{2}cA$ the two children of A. These may be called *complete or definite* numbers as they involve the definite article in their meaning.

Third. The proper mathematical expression for the eldest child of A will be c_1A, for the second c_2A, and so on.

When there is no quantitative symbol attached to c, the particle *any* is to be understood.

§ 3. There are in all four kinds of fundamental relationships. Of these I have already discussed the set of four s, σ, d, δ, denoting respectively the relationship of a man to his father, of a man to his mother, of a woman to her father, and of a woman to her mother; and also the set of two c, γ, denoting respectively the relationship of a person to his or her father, and of a person to his or her mother. There is another set of two, namely, the relationship of a man to his parent, and of a woman to her parent; and there is finally the relationship of greatest generality, *child of a person*, which is the relationship obtained by considering c and γ as equivalent (Part II. p. 8). Each of these relationships has its appropriate reciprocal.

§ 4. Let c be used to denote the relationship of *child*, then c^{-1} denotes *parent.* These symbols, together with m and f to express *male* and *female*, suffice to express the other fundamental relationships, and consequently (with the aid of auxiliary symbols) any relationship whatever. Thus—

${}_mc$	denotes	son of a person	${}_mc^{-1}$	denotes	father of a person
${}_fc$	,,	daughter of a person	${}_fc^{-1}$	,,	mother of a person
c_m	,,	child of a man	c_m^{-1}	,,	parent of a man
c_f	,,	child of a woman	c_f^{-1}	,,	parent of a woman
${}_mc_m$	,,	son of a man	${}_mc_m^{-1}$	,,	father of a man
${}_mc_f$	,,	son of a woman	${}_mc_f^{-1}$	,,	father of a woman
${}_fc_m$	,,	daughter of a man	${}_fc_m^{-1}$	,,	mother of a man
${}_fc_f$	,,	daughter of a woman	${}_fc_f^{-1}$	,,	mother of a woman

§ 5. We evidently have

$$\Sigma cU = \Sigma_m cU + \Sigma_f cU,$$

that is, all the children of any person are identical with all the sons of that person, together with all the daughters of that person.

This equation may be written—

$$\Sigma cU = \Sigma_{m+f} cU \quad . \quad . \quad . \quad (1),$$

similarly

$$\Sigma cU = \Sigma c_{m+f} U \quad . \quad . \quad . \quad (2),$$

and

$$\Sigma cU = \Sigma_{m+f} c_{m+f} U \quad . \quad . \quad . \quad (3).$$

We also have

$$\Sigma c^{-1} U = \Sigma_m c^{-1} U + \Sigma_f c^{-1} U,$$

that is, all the parents of a person are identical with all the fathers of the person, together with all the mothers. Here Σ on the left-hand side has the value $\dot{2}$, and in each case on the right-hand side the value $\dot{1}$. The equation may be written

$$\Sigma c^{-1} U = \Sigma_{m+f} c^{-1} U \quad . \quad . \quad . \quad (4).$$

Also

$$\Sigma c^{-1} U = \Sigma c^{-1}{}_{m+f} U \quad . \quad . \quad . \quad (5),$$

and

$$\Sigma c^{-1} U = \Sigma_{m+f} c^{-1}{}_{m+f} U \quad . \quad . \quad (6).$$

§ 6. Let us consider a genus-relationship of the second order, such as *grandchild*. We have

$$\Sigma ccU = \Sigma({}_m cc + {}_f cc)U \quad . \quad . \quad . \quad (1),$$

$$= \Sigma(c_m c + c_f c)U \quad . \quad . \quad . \quad (2),$$

$$= \Sigma({}_m c_m c + {}_m c_f c + {}_f c_m c + {}_f c_f c)U \quad . \quad . \quad (3).$$

Equation (1) expresses that all the grandchildren of a person are identical with all the grandsons of the person, together with all the granddaughters of the person. Equation (2) expresses that the same are identical with all the children of the sons of the person together with all the children of the daughters of that person; and equation (3) expresses that they are identical with all the sons of the sons, together with all the sons of the daughters, together with all the daughters of the sons, together with all the daughters of the daughters. The relationship can be expanded in other five ways by putting m or f after the last c.

It is not impossible, biologically, for certain individuals who are present in the first group of equation (3), that is in $\Sigma_m c_m c U$, to be present also in the second group, that is, in $\Sigma_m c_f c U$; and when we take the term *great-grandchild* and expand it in a similar manner there is no legal reason (according to the English Law) to prevent one and the same individual from appearing in two groups. The terms are mutually exclusive in respect of the *relations*, but not necessarily in respect of the individuals in which the relations exist. In the same man A there may be two great-grandsons of B. When it is necessary to denote the persons in which the relations exist, the Greek γ may be used instead of the corresponding c.

§ 7. *To find the number of genus-relationships in the n^{th} order.*

The first part of the Table of such relationships is as follows:—

Order.	Expression.	Index Expression.	Meaning.
0	1	c^0	self
I	c	c^1	child
	$\frac{1}{c}$	c^{-1}	parent
II	cc	c^2	grandchild
	$c\frac{1}{c}$	c^{1-1}	child of parent
	$\frac{1}{c}c$	c^{-1+1}	parent of child
	$\frac{1}{c}\,\frac{1}{c}$	$c\;^{2}$	grandparent

It will be observed that the terms for any order are derived from those of the preceding order by first prefixing c, and secondly by prefixing $\frac{1}{c}$ before each term. Hence the number of genus-terms for the nth order is 2^n.

§ 8. *To find the number of the elementary relationships of the n^{th} order.*

The nth order has 2^n genus-relationships. Consider any one of these. A distinction of sex can be introduced before each c or

c^{-1}, and also after the term. Hence, the number of different ways in which a distinction of sex can be r times introduced is equal to the number of combinations of $n+1$ things r together. The number of different relationships obtained by the expansion of a term in which a distinction of sex has been r times introduced is 2^r. Hence, the number of terms for one genus-notion is

$$1+(n+1)2+\frac{(n+1)n}{1\cdot 2}2^2+\ \ldots\ +2^{n+1},$$

that is, 3^{n+1}. Hence, the total number for the nth order is 2^n3^{n+1}. The number for the 5th order is 23,328.

Cor. 1. The number of varieties for the nth order is 2^{n+1}.

Cor. 2. The number of elementary relationships included in the first n orders is $\frac{18}{5}(6^n-1)$. For n being 5 the number is 27,990.

There have been those who have conceived the idea of framing a philosophical language (Max Müller, "Science of Language," vol. ii. lect. 2). The fact that without going beyond relationships involving more than seven generations, and without taking into account any combination of relationships, we have more than one million different elementary relationships in which two persons can be said to stand to one another, may serve to give some idea of the difficulties inherent in that task. At the same time it shows how mathematical analysis can step in where ordinary language fails.

§ 9. I shall now state briefly the properties of the different kinds of symbols required in this analysis, and first of the relationship symbols.

The order in which two fundamental symbols occur in a relationship is in general essential; that is, the symbols are in general *non-commutative* with one another. Thus cc^{-1} is not equivalent to $c^{-1}c$.

A relationship is not altered by varying the mode of *association* of its fundamental symbols. Thus $(c^2)c=c(c^2)$, that is, grandchild of child is equivalent to child of grandchild. Again $c^2(c^{-1}) = c(c^{1-1})$, that is, grandchild of parent is equivalent to child of brother or of sister or of self.

The symbol c has already been defined (§ 6) in such a manner as to satisfy the *distributive* law, and the symbol γ in such a manner as not to satisfy that law. For a complete investigation of the subject both symbols are required.

§ 10. Three kinds of indices are required; one kind to express the number of times a relationship symbol is repeated; a second to express the number of times one genus-relationship is present in a compound relationship; and the third to express the Boolian index which denotes the combination of the same relationship with itself. The first of these may be called the order-index, and the second the degree-index.

§ 11. *The Order-index.*—It follows from the preceding laws that $c^{p+q}=c^{q+p}$ and $c^{-p-q}=c^{-(q+p)}$, but c^{p-q} is not $=c^{-q+p}$.

The forms to which c^{p-q} can reduce are $c^{(p-1)-(q-1)}$, $c^{(p-2)-(q-2)}$, $c^{(p-3)-(q-3)}$, &c., until one of the indices is reduced to 0. It is evident that a relationship of an odd order, if reducible, can reduce only to one of an odd order, and one of an even order only to one of an even order.

It also follows from the preceding laws that $(c^p)^q=(c^q)^p$; that $(c^n)^{p-q}=c^{np-nq}$; but that $(c^{p-q})^n$ is not $=c^{pn-qn}$. For example $(c^2)^{2-1}$ $=c^2c^2c^{-2}=c^{4-2}$ that is, grandchild of grandchild of grandparent $=$great great grandchild of grandparent. But $(c^{2-1})^2=c^{2-1}c^{2-1}$ not $=c^{4-2}$ that is, grandchild of parent of grandchild of parent is not equivalent to great great grandchild of grandparent.

§ 12. *The Degree-index.*—The nature of this index may be best explained by taking an example. The relationship of full brother or sister is compounded of the relationship of half brother or sister on the father's side, and of half brother or sister on the mother's side, and may be expressed by

$$c^{\overline{\frac{1}{c}}^{\,2}} = c_m{}^{\frac{1}{c}} \cdot c_f{}^{\frac{1}{c}}.$$

Here the introduction of the vinculum or some such sign is necessary to distinguish the index of the degree from the index of the order. I use the sign · to denote logical combination. The index of the degree is not the Boolian index (which satisfies the law $x^2=x$), for the one quality is not wholly equivalent to the other quality, but agrees with it only to the extent of being a relationship of the same genus.

§ 13. *Partial numbers.* — Let r denote any relationship, and N a partial number; in counting NrA each rA counted must be different from any preceding one counted. But in such an expression as $(3+2)rA$, where two partial numbers are connected by $+$, it is not necessary that each of the individuals counted in the $3rA$ should be different from each of the individuals counted in the $2rA$. Hence $(3+2)rA$ is equivalent either to $5rA$, or $(3+2\cdot 1)rA$, or $(1+2\cdot 2)rA$ where the parts connected are now exclusive of one another. Similarly, $(3-2)rA$ is not necessarily equivalent to $1rA$; the expression is either irreducible or reducible, and if reducible may be either $(2-1)rA$ or rA.

A partial number placed before a sum of terms connected by the signs $+$ or $-$ is non-distributive. For example,

$$\Sigma c_m A = 2(c_f B + c_f C)$$

is best viewed as meaning that the children of the man A are identical with two children either of the woman B or of the woman C, rather than meaning that they are identical with two children of the woman B together with two children of the woman C. Upon this view the above equation means that

$$\Sigma c_m A = 2c_f B, \text{ or} = 1c_f B + 1c_f C, \text{ or} = 2c_f C.$$

§ 14. *Complete numbers.*—If, as before, r denote any relationship, then such an expression as $(\dot{3}+2)rA$ must be equivalent to $(1+2\cdot 2)rA$ where the former 2 is a coefficient. This follows because the sum of the rA is three. Similarly, $(\dot{3}-2)rA = 1rA$. A definite number is similar to an indefinite number in being non-distributive when placed before a sum of terms. Thus $\dot{3}\,(c_f B + c_f C)$ means that the children of the woman B together with those of the woman C amount to three.

§ 15. The symbol Σ expresses any complete number without denoting what the number is. For example, the equation

$$\Sigma c \text{ Henry VIII.} = \Sigma c \text{ Catherine of Arragon} + \Sigma c \text{ Anne Boleyn} + \Sigma c \text{ Jane Seymour},$$

is a less definite form of the statement

$$\dot{3}c \text{ Henry VIII.} = \dot{1}c \text{ Catherine of Arragon} + \dot{1}c \text{ Anne Boleyn}$$
$$+ \dot{1}c \text{ Jane Seymour.}$$

Thus Σ placed before a sum of terms is distributive, but its arithmetical value changes.

§ 16. Let N be used to denote any partial number in the same way as Σ is used to denote any complete number. The simplest kind of equation is where we have got one term equated to one term. Of this kind there are three forms according as, 1st, Σ occurs on both sides, 2d, Σ on the one, and N on the other side, 3d, N on both sides. Examples are

$$\dot{5}c \text{ Edward III.} = \dot{5}c \text{ Philippa of Hainault.}$$
$$3c \text{ John of Gaunt, Duke of Lancaster} = \dot{3}c \text{ Blanche.}$$
$$1c \text{ Margaret Tudor} = 1c \text{ Archibald, Earl of Angus.}$$

The first of those equations can be written in the form

$$\frac{\dot{5}}{\dot{5}}c \text{ Edward III.} = 1c \text{ Philippa,}$$

that is, each of the five children of Edward III. was a child of Philippa, and conversely. The second can be written in the form

$$\frac{3}{\dot{3}}c \text{ John of Gaunt} = 1c \text{ Blanche.}$$

Each of three children of John of Gaunt was a child of Blanche, the converse being each of the three children of Blanche was a child of John of Gaunt.

§ 17. The next simplest kind of equation is that in which one term is equated to two terms, as

$$5c_m A = 3c_f B + 2c_f C$$

that is, five children of the man A are identical with three children of the woman B together with two children of the woman C. This equation can be written in the other two forms

$$3c_f B = 5c_m A - 2c_f C\,,$$

and

$$2c_f C = 5c_m A - 3c_f B\,.$$

The rule for transforming such an equation is:—*Any symbol may be taken from the front of one side provided its reciprocal be placed in front of the other side; the reciprocal of the qualification* m *being* m, *and of* f *being* f. For instance, this rule applied to the first form of the above equation gives us

$$c_m A = \frac{1}{5}(3c_f B + 2c_f C)$$

each of three children of B and two children of C was a child of A.

$${}_m A = c^{-1}\frac{1}{5}(3c_f B + 2c_f C)$$

the man A was the parent of each of, &c.,

$$A = {}_m c^{-1}\frac{1}{5}(3c_f B + 2c_f C).$$

A was the father of each of, &c.

§ 18. If the sex symbols preceding and succeeding the expression $c\frac{1}{c}$ are the same, the expression may reduce to 1; but if the sex symbols are different, the expression cannot reduce to 1. If the sex symbols preceding and succeeding the expression $\frac{1}{c}c$ are the same, the expression must reduce to 1; and if these symbols are different the expression cannot reduce to 1. These laws apply to all states of society, with the exception that ${}_m\frac{1}{c}c_m$ does not necessarily reduce to 1 in communities where polyandry prevails.

Should the transformation of an equation result in bringing *mm* or *ff* between two relationship elements, as in $c_{mm}c$, such an expression is consistent, and *mm* is equivalent to *m* and *ff* to *f*; but should the transformation result in bringing *mf* or *fm* between two elements, the expression is contradictory.

§ 19. *Compound terms.*—The factors in a compound relationship are commutative with one another. For example, the relationship $c_m A . c_f B$ is equivalent to the relationship $c_f B . c_m A$. In connection with such an expression we have two kinds of quantitative symbols, 1st, those of the resultant; 2d, those of the components. Thus in $\Sigma(c_m A . c_f B)$ the compound representative term is first formed, and then the sum taken; whereas in $\Sigma c_m A . \Sigma c_f B$ the sum of each component is taken separately, and then the sums are combined. The results must be identical; hence $\Sigma(c_m A . c_f B) = \Sigma c_m A . \Sigma c_f B$. The Σ of the resultant is conditioned by the Σ's of the components in the following manner:—It cannot be greater than either of them; it cannot be less than their sum minus the Σ of ΣU; and it cannot be less than 0.

§ 20. Let r denote any relationship, and ρ an individual in which such a relationship exists (§ 6), then

$$\Sigma \rho U = \Sigma \left\{ \overline{r}^{1} + \overline{r}^{2} + \overline{r}^{3} + \ldots + \overline{r}^{n} \right\} U;$$

where the degree-index 1 denotes that the genus relationship occurs once and once only in the person; 2, that it occurs twice and twice only, and n that it occurs as often as is physically possible. For example,

$$\Sigma \gamma \frac{1}{\gamma} U = \Sigma \left\{ \overline{c\frac{1}{c}}^{1} + \overline{c\frac{1}{c}}^{2} \right\} U,$$

that is, the brothers and sisters of any person are identical with the half-brothers and sisters, together with the full-brothers and sisters. Again,

$$\Sigma \gamma^2 U = \Sigma \left\{ \overline{c^2}^{1} + \overline{c^2}^{2} \right\} U;$$

$$= \Sigma \overline{c^2}^{1} U,$$

in all countries where the marriage of brother and sister is prohibited.

This notation gives us the degree-index 0 as the proper symbol to express the negative particle *non;* for it means that the kind of relationship in question is not found at all in the person. $\Sigma \overline{c\frac{1}{c}}^{0} A$ expresses all the non-brothers and non-sisters of A to be found within the community of persons considered. Hence we have the following identity :—

$$\Sigma U = \Sigma \left\{ \overline{r}^{0} + \overline{r}^{1} + \overline{r}^{2} + \ldots + \overline{r}^{n} \right| A.$$

For example,

$$\Sigma_m U = \Sigma \left\{ \overline{{}_m c \frac{1}{c}}^{0} + \overline{{}_m c \frac{1}{c}}^{1} + \overline{{}_m c\, \overset{1}{c}}^{2} \right\} A$$

that is, all the men are identical with all the non-brothers of A, together with all the half-brothers of A, together with all the full-brothers of A. The equation can also be written in the form

$$\Sigma_m U = \Sigma \left\{ \overline{{}_m c_m \frac{1}{c}}^{0} \cdot \overline{{}_m c_f \frac{1}{c}}^{0} + \overline{{}_m c_m \frac{1}{c}}^{1} \cdot \overline{{}_m c_f \frac{1}{c}}^{0} + \overline{{}_m c_m \frac{1}{c}}^{0} \cdot \overline{{}_m c_f \frac{1}{c}}^{1} \right.$$
$$\left. + \overline{{}_m c_m \frac{1}{c}}^{1} \cdot \overline{{}_m c_f \frac{1}{c}}^{1} \right\}$$

which agrees with the Boolian form of development.

§ 21. The biological law that a person cannot be his or her own descendant is expressed by the equation $1 \cdot c^n A = 0$, where n denotes any integer from 1 upwards, and A denotes any person. The reciprocal aspect of this truth is that $1 \cdot c^{-n} A = 0$, that is, a person cannot be his or her own ancestor. The most general statement of the law is $\Sigma c^m . c^{-n} A = 0$, provided m and n are not both 0. This equation denies the possibility of the transmigration of souls, if A be considered to denote the identity of soul without necessary continuity of body.

§ 22. The effect of the laws of marriage of a nation is to annul within that nation certain compound relationships of the second degree. For example, $\Sigma c_m \cdot c_f c_m A = 0$, whoever A is. This means that the children of any man A who are also children of any daughter of the man A are none. Since A may be any man, substitute instead ${}_m \frac{1}{c}{}_f B$; the equation then becomes

$$\Sigma c_m \frac{1}{c}{}_f \cdot c_f c_m \frac{1}{c}{}_f B = 0$$

which means that a child of the father of any woman B cannot be the child of a daughter of the father of B. Hence $\Sigma c_m \frac{1}{c} \cdot c_f B = 0$, that is, a child of the father of any woman B cannot be the child of B. And this equation is equivalent to the preceding, because ${}_fB$ may be any woman. Again, it follows from the original equation that $\Sigma_f \frac{1}{c} c_m \cdot {}_f \frac{1}{c} c_f c_m A = 0$, that is, a mother of a child of the man A cannot be a mother of a child of a daughter of the man, hence

$$\Sigma_f \frac{1}{c} c_m \cdot {}_f c_m A = 0 .$$

It is evident from § 18 that an equation of this kind can be transformed by operating both in front and at the end of a factor, and hence the following rule :—*To transform a universal equation which has a compound term of the second degree equated to* 0, *suppose all the symbols brought to one factor in accordance with the Rule of* § 17, *then removing a symbol from the front gives one derived equation, and removing a symbol from the end gives another derived equation. Transform each of these two in a similar manner, then each of their four resultants, and so on until all the terms have been brought to the other factor. The total of these derived equations is the total number of transformations of the given universal equation.*

5. Note on a Singular Problem in Kinetics.

By Professor Tait.

The following problem presented itself to me nearly thirty years ago. I cannot find any notice of it in books, though it must have occurred to every one who has studied the oscillations of a balance :—

Two equal masses are attached to the ends of a cord passing over a smooth pulley (as in Attwood's machine). One of them is slightly disturbed, in a vertical plane, from its position of equilibrium. Find the nature of the subsequent motion of the system.

The interest of this case of small motions is twofold. From the peculiar form of the equations of motion, it is of exceptional mathematical difficulty. This is probably the reason for its not having been given as an example in Kinetics. And from the physical point of view it presents a very beautiful example of excessively slow, but continued, transformation of mixed potential and kinetic energy into kinetic energy alone.

If r and θ denote the polar coordinates of the disturbed mass, we have (supposing the curvature of the pulley to be large) by Lagrange's method—

$$2\ddot{r} - r\dot{\theta}^2 = -\tfrac{1}{2}g\theta^2,$$

$$\frac{d}{dt}(r^2\dot{\theta}) = -gr\theta.$$

Writing $\frac{1}{2}gr$ for r, and $\theta\sqrt{2}$ for θ, these become—

$$\ddot{r} - r\dot{\theta}^2 = -\theta^2,$$

$$\frac{d}{dt}(r^2\dot{\theta}) = -2r\theta.$$

Hence, *the motion of the disturbed mass is the same as that of a particle of unit mass under forces* $-\theta^2$ *along, and* -2θ *perpendicular to, the radius vector.*

[The work done by or against this system, along any arc of a curve, is the difference between the values of $r\theta^2$ at its ends.]

Changing to rectangular coordinates (x vertical), and maintaining the same degree of approximation as before, we have—

$$\left.\begin{aligned} \ddot{x} &= \frac{y^2}{x^2}, \\ \ddot{y} &= -\frac{2y}{x}. \end{aligned}\right\} \text{(1.)}$$

The first suffices, without farther analysis, to show that the vertical acceleration of the disturbed mass is persistently *downwards.* Hence, the result of the disturbance must be the continuous transformation of the mixed potential and kinetic energy, of the vibration originally given to the disturbed mass, into kinetic energy of translation of the whole system.

The equation of energy is easily seen to be—

$$\tfrac{1}{2}(\dot{x}^2 + \dot{y}^2) + \frac{y^2}{x} = \mathrm{C};$$

and here the term $\frac{y^2}{x}$ has an infinite series of successively diminishing maxima.

From some rough calculations I find that the amplitude of y increases, but much more slowly in percentage value than does x; so that the maximum inclination of the vibrating part of the string to the vertical constantly diminishes.

It would be interesting to obtain an approximate solution of the equations (1), and to compare the motion of the vibrating mass with that of *a simple pendulum whose cord is uniformly lengthened.* The equation for the latter case has been fully treated by Fourier in his *Théorie de la Chaleur.*

When both masses (in the original problem) are simultaneously disturbed, it appears from the equations of motion that that mass whose end of the cord vibrates through the greater *angle* will have downward acceleration. As this in the former case was found to be accompanied by a diminution of the angle, the angle of the ascending mass should increase; and thus it would seem that after a time the downward acceleration will change sign. Thus (if the string were long enough) the vertical motions of the system would be oscillatory. But this curious result cannot be verified without proceeding to a formal approximation. I have not found time to carry out this laborious but not difficult work.

Another variety of the problem is easily formed by seeking the requisite *ratio* of the two masses, so that the motion shall be wholly periodic, with a period equal to that of the vibration of the disturbed mass. This is, relatively to the above, a very simple question.

BUSINESS.

The following candidates were balloted for, and declared duly elected Fellows of the Society:—Mr John Horne and Mr B. Neeve Peach.

Monday, 21st March 1881.

Sir WYVILLE THOMSON, Vice-President, in the Chair.

The following Communications were read:—

1. The Earthquake of 28th November 1880 in Scotland and Ireland. By Charles Alexander Stevenson, B.Sc. Edin. (Communicated by Professor Geikie).

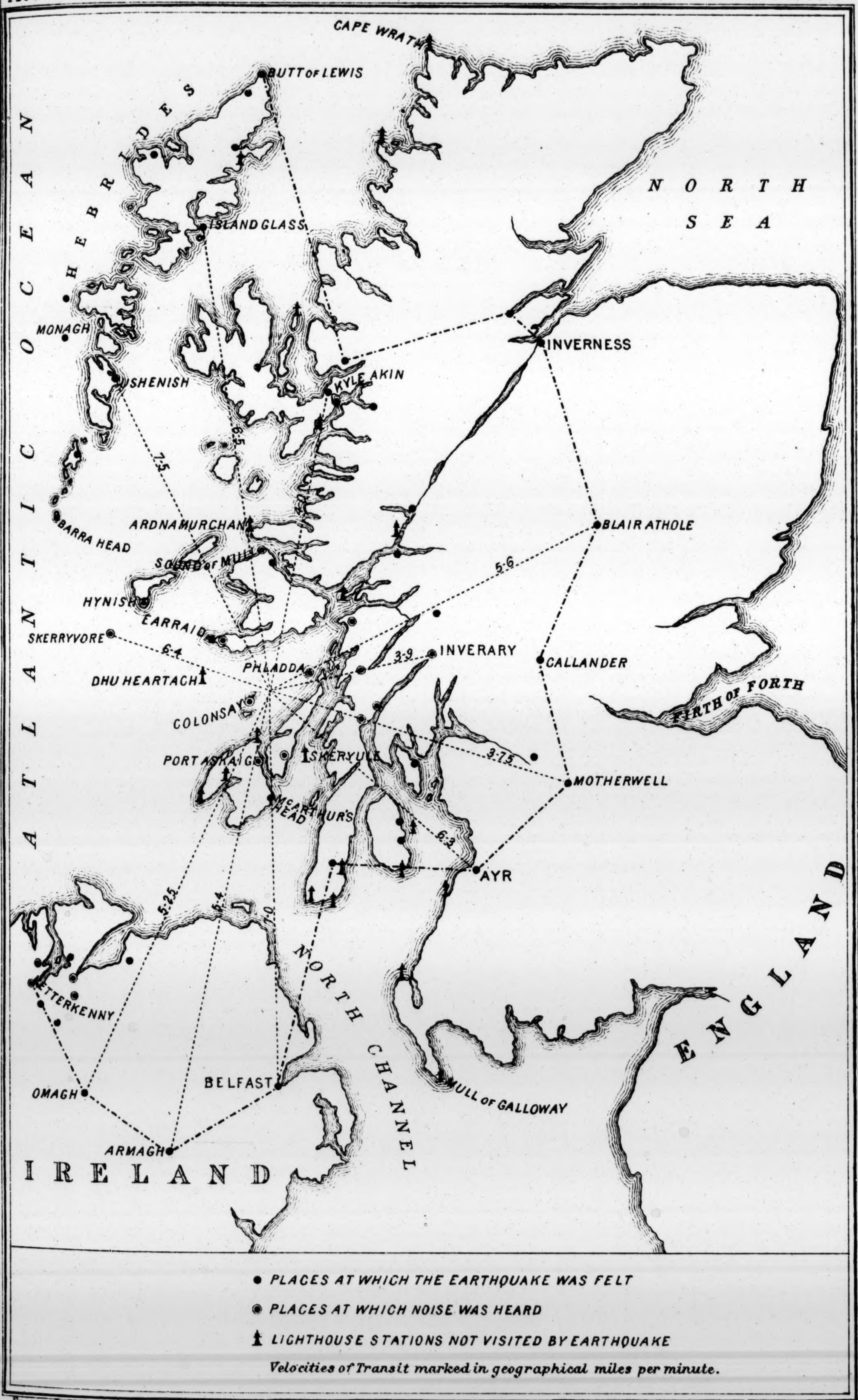
In 1877, my father, Mr David Stevenson, communicated to the Society a notice of earthquake shocks in Argyllshire (see Proceedings, vol. ix.) from observations made by the keepers at several lighthouses, which the late Dr Bryce undertook to use in his intended visit to the west of Scotland, to trace the source of the earthquake waves of 1877, an intention which, however, was suddenly terminated by his lamented accidental death at Inverness.

Another earthquake shock, which visited Scotland and the north of Ireland on the 28th November 1880, has afforded the means of acquiring further observations, of which I think (in connection with those formerly given) the Society may consider it not unimportant to have a record in their Proceedings. These observations, as communicated from the lighthouse stations, are in the following terms :—

Butt of Lewis.—" On the 28th we felt a shock of earthquake ; it made the bed I was lying in tremble. Those who were in the kitchen felt the shock quite distinctly ; it made the dishes on the dresser ring. It was also felt by a number of other people throughout the parish. There was a gale at the time accompanied by lightning and heavy showers of hail and sleet."

Island Glass.—" At 5.30 P.M. on the 28th, during a lull, the tower received a severe shock, which caused the glass of the mechanical lamp to shake, also the table and apparatus. During the night of 28th observed vivid flashes of lightning."

Monach.—" On Sunday evening the 28th November, at 5.20 P.M., the assistant, when on watch in the light-room, felt a strange shock, which shook the tower and made the glass on the lamp rattle. The motion was quite different from what is caused by a fierce blast of wind. The motion in gales is more of a rocking, but this was like a shake and a tremor throughout the whole building. It only continued for a few seconds. There was no heavy sea or lightning or



Engraved by Archibald & Peck Edinr

EARTHQUAKE OF 28TH NOVR 1880.

thunder to account for it, so that we can only surmise that it has been some shock of earthquake. I felt it myself in my bed, but so slight that it could have been easily mistaken for a gust of wind striking the house."

Ushenish.—"On the 28th, at 5.25 P.M., a slight shock of earthquake was felt distinctly both in the dwelling houses and light-room. It lasted only a few seconds. There was a lull in the wind at the time. It made the tower tremble, making the lamp-glass strike against the chimney, and several articles in the dwellinghouses were shaken at the same time."

Kyleakin.—"On the 28th, at 5.35 P.M., a shock of earthquake was felt in the light-room, causing the tower to shake very much, and the glass of the lamp to rattle against the funnel, which continued seven seconds. Shock felt at same time in Kyleakin village about one mile from the lighthouse."

Barrahead.—"Observed vivid flashes of lightning between 4.30 P.M. and 8 P.M. on the 28th. At a few minutes before 5.30 P.M. the assistant lightkeeper felt the tower shaking so much that everything in the light-room rattled and continued about a minute. We supposed it had been struck with lightning. We examined everything the following day, but could find nothing wrong. We have to-day (2d December) heard that there was a shock of earthquake felt in Barra, the same date and at the same time that the assistant lightkeeper felt the tower shaking."

Ardnamurchan.—"The earthquake of 28th November was not felt at this lighthouse. I had the first watch on the night of the 28th November, and I felt nothing unusual in the light-room, neither did any of the residents at the station feel anything."

Sound of Mull.—"An earthquake occurred here on the 28th about 6 P.M. (Greenwich). The occasional keeper was on watch, and he stated that the light-room and everything in it shook and rattled. In the dwellinghouses there were three distinct shocks in quick succession, accompanied by a noise as if a number of carriages were rapidly driven past The noise continued a few seconds after the trembling of the earth ceased. The evening was calm and sultry."

Hynish.—"On the 28th, at 6 P.M., a shock of earthquake was felt here; the oscillation being pretty strong the shaking of the houses and floors being plainly felt for about three or four seconds. A rumbling noise, as of distant thunder, was heard immediately preceding the shock."

Skerryvore.—"The lighthouse was visited by a very sharp shock of earthquake on the 28th November, at 5.18 P.M. It commenced with a low rumbling and rolling noise like distant thunder, and in a few seconds increased to a sharp rolling jerking motion. I was on watch at the time, and observed the lamp glass strike the funnel repeatedly. The whole tower from the foundation was in the same motion. The first assistant was in the kitchen at the time, and his description of the feeling was the same. The third keeper was in bed, and was started out of sleep, but could not tell the cause. We are of opinion the trembling motion lasted about eight seconds. The weather at the time was stormy, with strong breezes from S.W. At 8.25 P.M. observed several flashes of lightning, but no thunder heard. Next day we looked over the building, but couldnot find any damage done. I may state that this is the fifth shock that I have felt since I joined the service, and must say this one was the sharpest of the whole."

Earraid.—"On the 28th, at Earraid, a slight shock of earthquake was felt, and a rumbling sound for about two seconds at or about 6 P.M. also slightly felt on Iona."

Dhuheartach.—"At the rock (Dhuheartach) we felt nothing of the shock."

Phladda.—"On the 28th, at 5.18 P.M. we felt a shock of an earthquake, lasting from five to eight seconds, both in the light-room and dwellinghouses, making everything shake and rattle. The wave motion appeared to us to travel from W.S.W. to E.N.E. There was a long rumbling noise at the time."

Lowlandman's Bay (Shore Station for Skervuille Lighthouse).—The lightkeeper writes:—"My wife made the following statement to me on coming ashore from the lighthouse—that on the evening of the 28th, she felt as if the chair on which she sat was being withdrawn from under her, and heard a rumbling noise, the dishes were shaking. Neither I nor my assistant were sensitive of any shock of earthquake at the lighthouse, but lightning was seen by us that night."

MacArthur's Head.—"On the 28th, at 5.27 P.M. there occurred what appeared to us to be a slight shock of earthquake, which began with a trembling motion, which made the balcony doors and lighting apparatus rattle, immediately after which there was a peculiar wave motion from north to south in the tower, which lasted a few seconds, after which there was a second wave motion in the tower, more distinct than the first, for a few seconds. The lightkeeper in bed also felt the shock, but not so distinctly as the keeper on watch. There was no rumbling noise heard at the time, but the metal shades for adjusting the red light on the Islay side of the sound rattled very much." The time observed at this station is not reliable, as the clock was not in proper adjustment.

Having now given the lighthouse observations, I shall give a mere statement of the other places at which the earthquake was experienced, the information for which has been acquired from newspapers or from private sources:—Ness, Stornoway, Laxadale, Sandwick, Uig, Sheshader, Hyskeir, Barra, Dingwall, Inverness, Strome, Portree, Kyleakin, Loch Duich, Blair Atholl, Fort-William, Ballahulish, Tobermory, Island of Calla, Oban, Dalmally, Iona, Inverary, Callander, Colonsay House, Scallasaig, Port Askaig, Kilmichael, Kilmartine, Foord, Loch Gilphead, Cairnbaan, Loch Gair, Kelvinside (Glasgow), Motherwell, Rothesay, Brodick Castle, Lamlash, Campbeltown, Ayr, Fahan, Ramelton, Limavady, Leterkenny, Raphoe, Londonderry, Strabane, Omagh, Belfast, and Armagh.

The following lighthouse stations on the west coast of Scotland either were not visited by the earthquake, or its effects were so slight as not to render itself noticeable by the observers on watch:—Cape Wrath, Stourhead, Stornoway, Rona, Isle Oronsay, Corran, Ardnamurchan, Lismore, Dhuheartach, Rhuvaal, Skervuille, Lochindaal, Rhinns of Islay, Toward Point, Cumbrae, Lamlash, Pladda, Devaar, Turnberry, Mull of Kintyre, Sanda, Corsewall, Cairn Ryan, Mull of Galloway, Little Ross.

In the following table are given the state of the barometer and thermometer, and the general results of the observations at the different lighthouse stations, and along with them some of the more valuable observations which have been acquired from newspapers or private information, and I have to acknowledge the kindness of those who have given me assistance in the preparation of the data in the table, more especially the Commissioners of Northern Lighthouses, in granting access to the Lighthouse Returns; His Grace the

STATIONS and TIME OF SHOCK as mentioned by observers.	Greenwich.	Barometer.		Thermometer F.		Duration of the Disturbance.	Rainfall for November.	Direction in which wave appeared to travel.	Character of Sound.
	p.m.	9 a.m.	9 p.m.	9 a.m.	9 p.m.		Ins.		
Butt of Lewis, . .	..	29.20	29.40	50°	45°	..	3·84	..	
Island Glass, at 5.30,	5.56	29.20	29.50	48°	48°	..	5·61	..	
Monach, at 5.20. .	5.51	29.30	29.52	50°	49°	a few secs.	5·7	..	
Ushenish, at 5.25, .	5.53	29.16	29.46	50°	50°	a few secs.	2·1	..	
Kyleakin, at 5.35, .	5.58	29.40	29.64	50°	50°	7 secs.	6·51	..	
Barrahead, a few mins. before 5.30, .	..	28.85	28.90	50°	50°	about a min.	2·85	..	
Blair Atholl, at 5 mins. before 6, .	5.55	..	..	..	..	..	..	..	
Sound of Mull, about 6, ...	..	29.61	29.74	50°	48°	..	1·17	..	Rumbling noise during & after shocks.
Hynish, at 6,? . .	..	..	..	..	..	about 3 or 4 secs.	..	..	Preceded by rumbling noise as of distant thunder.
Skerryvore, at 5.18,	5.46	29.89	29.57	52°	51°	8 secs.	..	..	Preceded by rumbling noise like distant thunder.
Motherwell, at 6, .	6.0	..	..	..	..	..	..	..	
Oban, about 5.30, .	..	..	..	..	..	..	..	..	Rumbling noise.
Earraid, at or about 6,	..	..	..	..	..	2 secs.?	..	..	Rumbling sound (for about 2 secs.?).
Phladda, at 5.18, .	5.42	29.80	30.00	51°	49°	5 to 8 secs.	4·50	W.S.W. to E.N.E.	Long rumbling noise.
Inveraray, b'tween 5.45 and 5.50, . Inveraray, 5.50, .	5.48¾	..	..	..	..	2 secs.	..	..	Sharp rumbling noise
Callander, a few mins. before 6, .	..	..	..	..	..	several secs.	..	W.S.W. to E.N.E.	
Colonsay House, .	..	..	..	..	..	..	..	..	Rumbling sound preceding shock.
Lowlandman's Bay,	..	..	..	..	..	..	..	..	Rumbling sound.
Port Askaig, between 5.40 & 5.45,	5.40 5.45	..	..	..	..	..	..	N.E. to S.W.?	Heavy rumbling sound.
MacArthur's Head, at 5.27.	..	29.78	29.90	..	..	see Report.	7·04	N. to S.	
Ayr, at 5.50, . . .	5.50	..	..	..	..	several secs.	..	..	
IRELAND.									
Ramelton, at 5.15, .	5.46?	..	..	..	..	about 5 secs.	..	..	Preceded by rumbling sound for 3 secs.
Londonderry, about 5.30, ...	6.1 ?	..	..	..	..	..	..	.	Rumbling sound.
Leterkenny, at 5.25,	5.56?	..	..	..	..	ab. 20 secs.	..	..	Rumbling noise.
Donemana, at 5.27,	5.57?	..	..	..	..	..	..	..	Noise resembling distant thunder.
Strabane, about 23 mins. to 6, . . .	6.7 ?	..	..	..	..	..	..	..	
Omagh, about 5.30,	6.0	..	..	..	..	..	..	S.W. to N.E.	
Belfast, at 5.28, . .	5.53	..	..	..	..	..	..	..	
Armagh, at 5.35, .	6.0	..	..	..	..	..	..	..	

Duke of Argyll; the Rev. Dr Robinson of Armagh; Mr William Philip, resident engineer, Londonderry; Capt. Graham, steamer "Pharos"; Mr David Gordon of Bathgate; and Mr R. L. Mackintosh, Inverness.

I may observe that this earthquake occurred in the month of November, during a wet and stormy period, the average rainfall for the month at the different places of observation being 4·4 inches, which wet period had been preceded by an unusually dry summer and spring; that it was accompanied by a widespread thunder storm, but no sudden change of barometer or thermometer; that the average height of the barometer at the lighthouse stations was, at 9 A.M., 29·4 inches; and at 9 P.M. 29·5 inches; and that the average temperature at 9 A.M. was 50° F. and at 9 P.M. 48° F.

The area over which it was felt from Butt of Lewis in the Hebrides to Armagh in Ireland, and from Barrahead in the Hebrides to Blair Atholl, amounted to at least 19,000 square geographical miles, though to what additional extent it may have been propagated into the Atlantic it is impossible to say.

The effects of this earthquake, as reported by the lightkeepers, show that it was a rather sharp shock, but fortunately that no damage was done, due no doubt to the massive structures of all our exposed lighthouse towers, and, judging generally from the reports of the shock, the undulation seems to have been of an "up and down" character like a wave of the sea.

The "breadth" of the undulation of 1839, which emanated from Comrie, and which is described by Mr David Milne-Home in an article in the "Edinburgh Philosophical Journal" for 1843, was calculated by him to have been about 20 feet, but the wave of the earthquake now under consideration must have very much exceeded the Comrie one in breadth, for a wave 20 feet broad, travelling with a velocity of 568 feet per second (which will be shown afterwards to have been the average velocity of transit of the wave of the earthquake of 1880) would pass a point on the earth's surface in $\frac{1}{28}$th of a second, which evidently is too short a time to produce the effects observed by the lightkeepers; but, calculating the breadth of this wave from the minimum time its effects were felt, which was two seconds, and from its average velocity of transit it would appear that the breadth of the wave was fully 1100 feet, which I think is a more probable breadth than 20 feet.

The shock was felt very distinctly at some stations, whilst at others only a few miles distant it was not perceived at all. With reference to this fact, it seems necessary to remark that at the time of the shock there happened to be a keeper *on watch* in every lighthouse, as the earthquake occurred after sunset, at a time when the lamps were lighted.

Two instances will be sufficient to show how capricious the indications of the shock were.

1. At Skerryvore the shock was more severe than at any other station, yet not a trace of it was felt at Dhuheartach lighthouse, only twenty miles distant. These two lighthouse towers are very similarly situated, both being absolutely built *into* solid rocks of small extent lying in the open sea, the nearest land to either of them being about ten miles distant.

Being unable to fix the geological ages of the two rocks, I submitted specimens of them to Professor Geikie, who kindly examined them, and states by letter that he finds "the Dhuheartach rock to be a dolerite, identical in external and microscopic characters with the more coarsely crystalline dolerites of Mull, Eig, &c. I have not the least doubt that it is a portion of the volcanic plateau which extends more or less broken from Antrim up into Faroe Islands and Iceland. The Skerryvore rock is one of the crystalline schists, and of much higher antiquity than the rock of Dhuheartach."

2. Again the earthquake was felt at the Sound of Mull lighthouse, but was not felt at Ardnamurchan, situated on the other side of the Sound of Mull, and only seven miles distant. The Sound of Mull and Ardnamurchan lighthouses are both founded on igneous rocks of the Miocene age. Judging from this case, one might come to the conclusion that the deep cleft or basin of the Sound of Mull had cut off the earthquake wave from Ardnamurchan, but on the same grounds it should have been cut off at Kyleakin, MacArthur's Head, and other places, and after a careful study of the Chart and Geological Map, I have come to the conclusion that it is impossible to account for the different effects of the earthquake, as observed at places within the agitated area, either by the configuration of the land or by the directions or positions of the principal lines of fault or of the trap dykes, but this much is shown that of twenty-two lighthouse observers between Cape Wrath and the Mull of Galloway who were

situated on the older formations (Laurentian, Cambrian, and Metamorphosed Lower Silurian), eleven felt the shock, whilst of thirteen observers situated on newer rocks, it made itself known only to two of them, and it may therefore be assumed that it was more sensibly developed on the older rocks of Scotland than on those of more recent formations. Judging from the times of occurrence of the earthquake, I think I am warranted in coming to the conclusion that the seismal focus was situated near Phladda lighthouse, which it may be remarked lies nearly in the line of the great fracture which runs from Inverness through Scotland in a south-westerly direction. It may be interesting to notice that the earthquake shocks of 1877, communicated by Mr David Stevenson, had their origin in the same district, having been experienced at Phladda, Hynish, Sound of Mull, and Lismore.

STATIONS.	Distance from Source in Geog. Miles.	Calculated Velocity in Miles per Minute.	
Inverary, . .	34	3·9 mean	LAND JOURNEYS.* Inverary, Kyleakin, Motherwell, Blair Atholl, Armagh, and Omagh,—mean velocity 4·65 miles per minute. SEA JOURNEYS. Skerryvore, Ayr, Monach and Ushenish, Belfast, and Island Glass, —mean velocity 6·74 miles per minute.
Skerryvore, . .	38	6·4	
Ayr, ...	63	6·3	
Kyleakin, . . .	69	4·0	
Motherwell, . .	75	3·75	
Blair Atholl, . .	84	5·6	
Monach and Ushenish,	90	7·5 mean	
Belfast, . . .	91	7·0	
Island Glass, . .	104	6·5	
Omagh, . . .	105	5·25	
Armagh, . . .	108	5·4	

The exact focus, however, is not certain, but as a centre from which to calculate the velocity, a point has been chosen lying S.S.W.

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* If the wave in its course passed over a greater extent of land than of sea, it has been classified as a land journey, and *vice versa.*

of Phladda lighthouse and north of MacArthur's Head lighthouse, as the wave motion is described by the lightkeepers at these stations to have come in these directions; and having no less than five observations of time by lightkeepers, and seven trustworthy observations from other places, I have been enabled to determine the following results, as to what may be held to have been the velocity of transit of the earthquake wave, the time at the source being taken as 5.40 P.M. (Greenwich), which assumes that the wave travelled from the source to Phladda at a velocity of 6.74 miles per minute, which is the average velocity over the sea, and the distance from Phladda to the source being only 13 miles, any difference between this assumed velocity and the actual velocity will only affect the general result to a very small extent.

It appears, then, from this table, that the velocity has varied from 3·75 geographical miles per minute to 7·5 miles per minute in different directions from the source, the greater velocities being over the sea, probably due to the fact that in these directions the crust of the earth is thinner and lighter, and consequently more easily thrown into vibration. Thus the average velocity on sea journeys, was 6·74 miles per minute, and on land journeys, 4·65 miles per minute, the mean of the whole being about 5½ miles per minute. On the Chart the dotted line shows roughly the limit or range of the earthquake landwards, in so far as I have been enabled to ascertain it, and it will be seen that the earthquake wave was apparently propagated farthest in directions over the sea-basin, the wave being more quickly dissipated by passing over the land with its mountain chains.

It is interesting to notice, that of the fourteen observers within a radius of 38 miles from the source who felt the shock thirteen of them mention having heard a noise, and no observers in Scotland, at greater distances, mention noise as an accompaniment of the earthquake. The stations where the noise was heard were for the most part situated on hard dense rocks, with little or no soil near them.

The average duration of the disturbance for observers within a 38 mile radius from the source is 4·4 seconds.

The most of the reports received from Ireland by newspaper notices or otherwise I had no means of personally investigating; but all of them, as will be seen in the tabular statement, give the times at which the shock was felt as later than that reported from Phladda. Three of the Irish reports which I was enabled to inquire into, at Omagh, Belfast, and Armagh, give times which agree almost exactly with those which might be expected on the assumption that the wave felt at those places had been propagated direct from Phladda; and it is therefore probable that the earthquake disturbance in Scotland and Ireland proceeded from one and the same cause. But it is not a little remarkable that in and around Leterkenny "rumbling noises" were heard which, as already pointed out, were only heard in Scotland within a radius of 38 miles of the source, and the shock was also more severely felt than would have been expected in a spot removed so far from the source. This I think can only be accounted for on the hypothesis that the arrival of the earthquake wave from Scotland, generated in the neighbourhood of Leterkenny a second source of disturbance (not at all an improbable event), the effects of which were only local. The exact time, however, of this disturbance has unfortunately not been determined, as the reports from the north of Ireland are not sufficiently exact.

Having thus laid before the Society at some length the facts, so far as I have been able to ascertain them, regarding this very marked earthquake phenomenon, I have only to add in the form of a digest some of the principal conclusions to which this investigation appears to lead.

1. That the earthquake occurred in the month of November, a month in which many of the British earthquakes are recorded to have happened.

2. That it occurred after a wet period which had been preceded by an unusually dry summer and spring. That there was a widespread thunderstorm at the time, and that the barometer was rising slowly over the greater part of the west of Scotland, the average height of the barometer at the lighthouse stations at which the earthquake was felt being at 9 A.M. 29·4 inches, and at 9 P.M. 29·5 inches: The thermometer at 9 A.M. averaged 50° F. and at 9 P.M. 48° F.

3. That the seismal area was about 19,000 square geographical miles, the shock having been felt as far north as the Butt of Lewis, as far south as Armagh in Ireland, as far east as Blair Atholl, and as

far west as Barrahead, though how much farther it was propagated into the Atlantic it is impossible to say.

4. That the range of the earthquake or distance to which the wave was propagated was greater over the sea than over the land.

5. That the earthquake was not a simultaneous shake over the disturbed area, but was produced by a wave propagated from a centre.

6. That the undulation seems to have been chiefly of an "up and down" character like a wave of the sea, and that, calculating the breadth from the mean velocity of transit, and the minimum duration of the shock, it appears to have been fully 1100 feet in breadth.

7. That the observations warrant the assumption that a spot near Phladda lighthouse was the source, and calculating the velocities of transit with a point 13 miles S.S.W. of Phladda as a centre, the wave travelled with a greater velocity over the sea-basin than over the land, probably due to the fact that over the sea there was a thinner and lighter crust to throw into vibration, the average velocity on sea journeys being 6·74 geographical miles per minute, and the average velocity on land journeys 4·65 miles per minute, the mean of the whole being about 5½ miles per minute.

8. That the source of the earthquake lay at or near the great fracture, which runs in a south-westerly direction from Inverness, and that the shock was probably due to a rupture of the crust of the earth at this very distinct line of fracture.

9. That all the observers who heard noises agree in stating that it was a "rumbling" sound.

10. That of the fourteen observers within a radius of 38 miles from the source, who felt the shock, thirteen of them mention having heard the rumbling sound, and none of the other observers in Scotland mention noise as an accompaniment of the earthquake, and hence that the noise was confined chiefly, if not entirely, to places situated near the source.

11. That the stations where the noise was heard were for the most part situated on hard dense rocks with little or no soil near them.

12. That the average duration of the disturbance was 4·4 seconds, for observers within the sound area.

13. That of twenty-two lighthouse observers between Cape Wrath and the Mull of Galloway, who were situated on the older formations (Laurentian, Cambrian, and Metamorphosed Lower Silurian), eleven felt the shock, whilst of thirteen observers situated on newer rocks, it made itself known only to two of them; and that the earthquake was therefore more generally felt on the older rocks of Scotland.

14. That stations situated near one another, and on the same formation, did not necessarily both receive the shock, and that faults or trap dykes did not seem to affect the passage or intensity of the wave in any way.

15. That the observations of time at Armagh, Belfast, and Omagh, show that the shocks at these places were most probably propagated direct from Phladda in Scotland, and that the severity of the shock, and the "rumbling" noises heard in and around Leterkenny, were probably due to a second and local source of disturbance, generated by the arrival of the shock from Phladda.

2. On the Classification of Statistics. Part I.

By Mr P. Geddes.

3. On Professor Cayley's Theorem regarding a Bordered Skew Determinant. By Mr Thomas Muir, M.A.

(This paper is to be found in the *Quarterly Journal of Mathematics*, vol. xviii.).

4. The Law of Extensible Minors in Determinants.

By Mr Thomas Muir, M.A.

5. Additional Note on a Problem of Arrangement.

By Mr Thomas Muir, M.A.

1. The present note is a continuation of a short paper which appeared in the Proceedings of the Royal Society of Edinburgh for session 1876–77. The problem in question is that referred to in Professor Tait's "Memoir on Knots," viz.:—*To find the number of possible arrangements of a set of* n *things, subject to the conditions that the first be not in the last or first place, the second not in the*

first or second place, the third not in the second or third place, and so on.

It being understood that U_n denotes the said number of arrangements, the concluding lines of the paper referred to will show to what extent the problem was solved.

"Hence for the determination of U_n when U_{n-1}, U_{n-2}, ... are known we have

$$\left.\begin{aligned} U_n = (n-2)U_{n-1} + (2n-4)U_{n-2} &+ (3n-6)U_{n-3} \\ &+ (4n-10)U_{n-4} + (5n-14)U_{n-5} \\ &+ (6n-20)U_{n-6} + (7n-26)U_{n-7} \\ &\cdots\cdots\cdots\cdots\cdots\cdots \\ &+ \frac{1-(-1)^n}{2}, \end{aligned}\right\} \quad (1)$$

where the coefficients proceed for two terms with the common difference $n-2$, for the next two terms with the common difference $n-4$, for the next two terms with the common difference $n-6$, and so on.

"And as it is self-evident that $U_2 = 0$, we obtain

$$\begin{aligned} U_3 &= 1U_2 + 1 && = 1 \\ U_4 &= 2U_3 && = 2 \\ U_5 &= 3U_4 + 6U_3 + 1 && = 13 \\ U_6 &= 4U_5 + 8U_4 + 12U_3 && = 80 \\ U_7 &= 5U_6 + 10U_5 + 15U_4 + 18U_3 + 1 && = 579 \\ U_8 &= 6U_7 + 12U_6 + 18U_5 + 22U_4 + 26U_3 && = 4738, \end{aligned}$$

and so forth."

What is aimed at now is to reduce the above equation of differences and thereafter to obtain the generating function of U.

2. From (1) we have

$$\left.\begin{aligned} U_{n-2} = (n-4)U_{n-3} + (2n-8)U_{n-4} &+ (3n-12)U_{n-5} \\ &+ (4n-18)U_{n-6} + (5n-24)U_{n-7} \\ &+ \cdots\cdots\cdots\cdots\cdots\cdots \\ &+ \frac{1-(-1)^n}{2}, \end{aligned}\right\}$$

and therefore by subtraction

$$\begin{aligned} U_n - U_{n-2} = (n-2)U_{n-1} &+ (2n-4)U_{n-2} \\ &+ (2n-2)(U_{n-3} + U_{n-4} \ldots\ldots + U_3) \quad \ldots (2). \end{aligned}$$

Consequently, of course,

$$U_{n-1}-U_{n-3}=(n-3)U_{n-2}+(2n-6)U_{n-3}$$
$$+(2n-4)(U_{n-4}+U_{n-5}+\ldots\ldots+U_3),$$

and thus we are enabled to eliminate $U_{n-4}+U_{n-5}+\ldots+U_3$. The result of doing so is

$$\begin{aligned}&(n-2)(U_n-U_{n-2})-(n-1)(U_{n-1}-U_{n-3})\\ &=(n-2)^2U_{n-1}+\left.\begin{array}{l}(n-2)(2n-4)\\-(n-1)(n-3)\end{array}\right\}U_{n-2}+\left.\begin{array}{l}(2n-2)(n-2)\\-(n-1)(2n-6)\end{array}\right\}U_{n-3},\end{aligned}$$

or

$$(n-2)U_n=(n^2-3n+3)U_{n-1}+(n^2-3n+3)U_{n-2}+(n-1)U_{n-3}\quad(3).$$

Putting $(n-1)$ for n we have also

$$(n-3)U_{n-1}=(n^2-5n+7)U_{n-2}+(n^2-5n+7)U_{n-3}+(n-2)U_{n-4},$$

and therefore from this and (3) by subtraction

$$(n-2)U_n=(n^2-2n)U_{n-1}+(2n-4)U_{n-2}-(n^2-6n+8)U_{n-3}-(n-2)U_{n-4},$$

or $$U_n=nU_{n-1}+2U_{n-2}-(n-4)U_{n-3}-U_{n-4}\quad\ldots\ldots\quad(4)$$

Further, partitioning the term $2U_{n-2}$ into $\frac{n}{n-2}U_{n-2}+\frac{n-4}{n-2}U_{n-2}$, this may be written in the form

$$U_n-nU_{n-1}-\frac{n}{n-2}U_{n-2}=\frac{n-4}{n-2}\left(U_{n-2}-\overline{n-2}\,U_{n-3}-\frac{n-2}{n-4}U_{n-4}\right)$$

or, say,

$$V_n=\frac{n-4}{n-2}V_{n-2},$$

whence

$$V_n=\frac{n-4}{n-2}\cdot\frac{n-6}{n-4}\cdot\frac{n-8}{n-6}\ldots\ldots\frac{2}{4}V_4,$$

or

$$=\frac{n-4}{n-2}\;\frac{n-6}{n-4}\;\frac{n-8}{n-6}\ldots\ldots\frac{3}{5}V_5,$$

according as n is even or odd. But

$$V_4=U_4-4U_3-2U_2=-2,$$

and

$$V_5=U_5-5U_4-\frac{5}{3}U_3=\frac{4}{3}.$$

Hence

$$V_n = -\frac{4}{n-2}\ (n \text{ even}),$$

$$= +\frac{4}{n-2}\ (n \text{ odd}),$$

that is

$$U_n - nU_{n-1} - \frac{n}{n-2}U_{n-2} = (-1)^{n-1}\frac{4}{n-2},$$

or

$$U_n = nU_{n-1} + \frac{n}{n-2}U_{n-2} + (-1)^{n-1}\frac{4}{n-2} \quad . \quad . \quad . \quad (5).$$

From this the successive values of U_n are got with ease.

3. To obtain the generating function of U we return to (4), and write it in the form

$$U_n = (n-1)U_{n-1} + U_{n-1} + 2U_{n-2} - (n-3)U_{n-3} + U_{n-3} - U_{n-4},$$

so that if u, a function of x, be the generating function, its differential equation is at once seen to be of the form

$$u = x^2\frac{du}{dx} + xu + 2x^2u - x^4\frac{du}{dx} + x^3u - x^4u + \phi(x).$$

By trial, however, $\phi(x)$ is readily found to be $x^5 - 2x^4 + x^3$, consequently the equation is

$$(x^4 - x^2)\frac{du}{dx} + (x^4 - x^3 - 2x^2 - x + 1)u = x^5 - 2x^4 + x^3.$$

Integrating in the usual way we first find

$$\int\frac{x^4 - x^3 - 2x^2 - x + 1}{x^4 - x^2}\,dx = x + \frac{1}{x} - \log\frac{x^2-1}{x},$$

$$\text{and} \quad \therefore\ \left.\begin{array}{l} u = exp\left(-x + \frac{1}{x} + \log\frac{x^2-1}{x}\right) \\ \quad + \int\left\{exp\left(x + \frac{1}{x} - \log\frac{x^2-1}{x}\right) \times \frac{x^5 - 2x^4 + x^3}{x^4 - x^2}\right\}dx. \end{array}\right\}$$

$$= \left(x - \frac{1}{x}\right)e^{-\left(x+\frac{1}{x}\right)}\int\left\{e^{x+\frac{1}{x}} \times \frac{x}{x^2-1} \times \frac{x^3(x-1)^2}{x^2(x^2-1)}\right\}dx$$

$$= \left(x - \frac{1}{x}\right)e^{-\left(x+\frac{1}{x}\right)}\int e^{x+\frac{1}{x}}\frac{x^2}{(x+1)^2}\,dx.$$

This does not really differ from Professor Cayley's result (Proc. R.S.E. 1876–7). The apparent difference is due to the fact that in the one case u is assumed to be of the form $U_3x + U_4x^2 + \ldots$, and in the other of the form $U_3x^3 + U_4x^4 \ldots$.

6. On the Oxidation of Ferrous Salts.

By Mr J. Y. Buchanan.

In this paper the action of permanganate of potash on ferrous salts in hydrochloric acid is studied, and a satisfactory method of titrating such solutions is indicated. Further, a short study is made of the action of chlorates, perchlorates, and nitrates on acid ferrous salts under various conditions. The results have a certain interest for the analytical chemist.

The following solutions were used:—

Ferrous Sulphate.—Ordinary recrystallised green vitriol was used.

(*a*) 5·857 grammes $FeSO_4 + 7H_2O$ dissolved in water and diluted till the solution weighed 290 grammes. This solution contains 0·0407 grammes iron in 10 c.c.

(*b*) 4·4600 grammes $FeSO_4 + 7H_2O$ (=0·8977 grammes iron) were dissolved in water and made up to 145·5 grammes. The solution therefore contains 0·062 grammes iron in 10 c.c.

(*c*) 25·222 grammes $FeSO_4 + 7H_2O$ were dissolved in water and made up to 508 c.c. When filled up to the mark, and before adding the extra 5 c.c. water, the 500 c.c. solution weighed 514 grammes, therefore the specific gravity of the solution is 1·028 at 15° C. This solution when fresh contains 0·1 gramme iron in 10 c.c. It was used for most of the observations, and extending over nine days, during which time it gradually deposited a little ochreous matter. Compared with permanganate 10 c.c. required

March 11, 17·85 c.c. permanganate.
March 19, 17·6 „

Hence the alteration had not been very great, considering that during these nine days the solution had been consumed in portions of 10 c.c. at a time.

Chlorate of Potash.—3·654 grammes recrystallised chlorate of potash were dissolved in water and made up to 1 litre. 10 c.c. of this solution oxidise 0·1 gramme iron from ferrous to ferric salt.

Perchlorate of Potash.—The perchlorate was obtained from the

University laboratory, and was very pure. On analysis the following results were obtained :—

Weight of salt, . . .	0·6208 grammes.
Weight of salt after heating (KCl),	0·3330 „
Difference oxygen, . .	0·2878 „
Chlorine in residue, . .	0·1581 „

Whence we have the following composition per cent. :—

	Found in Salt.	Calculated in $KClO_4$.
Potassium, . .	28·18	28·22
Chlorine, . . .	25·46	25·61
Oxygen, . . .	46·36	46·17
	100·00	100·00

3·0938 grammes $KClO_4$ oxidise 10 grammes iron from the ferrous to the ferric state. 3·0940 grammes were dissolved in warm water and made up to a litre at 9° C.

Nitrate of Potash.—6·018 grammes KNO_3 oxidise 10 grammes iron from the ferrous to the ferric state. 6·019 grammes were dissolved in water and made up to a litre. The nitrate of potash was purified by recrystallisation.

The *sulphuric acid* used to acidify the solutions was made by diluting 1 part by weight of pure oil of vitriol with 9 parts by weight of water. It contains, therefore, very closely one gramme-molecule per litre (H_2SO_4).

Permanganate of Potash.—This solution was made by dissolving 3·163 grammes crystallised salt in water and making up to a litre. 3·162 grammes $= \frac{KMnO_4}{50} = 0{\cdot}02KMnO_4$. Tested with the double sulphate of iron and ammonia, 17·9 c.c. were found to be required to oxidise 0·1 gramme iron from the ferrous to the ferric state. 3·163 grammes $KMnO_4$ oxidise 5·602 grammes iron from ferrous to ferric, therefore 17·9 c.c. of the above solution ought to oxidise 0·1003 gramme iron.

It is well known that the use of permanganate of potash for titrating ferrous salts in hydrochloric acid is discouraged, and indeed prohibited by the highest authorities in analytical chemistry. As a matter of fact, however, there is very little inaccuracy attending its use in hydrochloric acid solution, which is as dilute as the sulphuric acid solution is when it is commonly titrated. But the chief want of the analyst is the power to titrate strongly acid hydrochloric solutions of iron with permanganate, and I find that this can be done without difficulty. As long as there is ferrous salt in the solution the permanganate devotes itself exclusively to it; but as soon as it is all transformed into ferric salt the permanganate at once attacks the hydrochloric acid, and the characteristic odour of enchlorine is at once perceived. If the permanganate is added with sufficient care to avoid local supersaturation, the appearance of this odour indicates with very considerable sharpness the moment when all the iron has been oxidised. It can, however, also be indicated clearly to the eye. If one or two drops of a dilute solution of pure ferricyanide of potassium be added to the ferrous solution so as to colour it blue without producing a precipitate, then on titrating with permanganate the disappearance of the ferrous salt is indicated by the simultaneous disappearance of the blue colour. This is illustrated in the following table. For each experiment 10 c.c. of ferrous sulphate solution (*a*), containing 0·0407 gramme iron, were acidified either with normal sulphuric acid ($0{\cdot}5H_2SO_4$) or with fuming hydrochloric acid (12·6HCl), diluted with water so as to bring the volume to about 60 c.c., then titrated with permanganate in hydrochloric acid solution, with the addition of enough ferricyanide to colour the solution blue.

Table I.

	Number of Experiment.						
	1.	2.	3.	4.	5.	6.	7.
Ferrous sulphate (*a*), . c.c.	10	10	10	10	10	10	10
Sulphuric acid ($0{\cdot}5H_2SO_4$), ,,	...	...	20	...	...	...	...
Hydrochloric acid (12·6HCl), ,,	10	10	...	25	25	25	25
Water, ... ,,	30	30	30	25	25	25	25
Permanganate, . . ,,	7·55	7·5	7·5	7·6	7·45	7·7	7·6

From this table it will be seen that with 10 c.c. fuming hydrochloric acid the results are quite as good as with sulphuric acid.

With 25 c.c. hydrochloric acid the method becomes a little strained; but it can be perfectly well carried out if care is taken to add the permanganate slowly so as to avoid a local excess, which would involve oxidation of the hydrochloric acid. This happened in experiment No. 6. In No. 5, which was also otherwise unsatisfactory, the ferricyanide had produced a precipitate which should always be avoided.

In Table II. will be found the results of experiments on the action of chlorate of potash and of perchlorate of potash solutions on ferrous sulphate in sulphuric acid and in hydrochloric acid solution when left together for a short time.

TABLE II.

	Number of Experiment.						
	8.	9.	10.	11.	12.	13.	14.
Ferrous sulphate (*b*), . . c.c.	10	10	10	10	10	10	10
Sulphuric acid (H_2SO_4), . ,,	20	20	20	20	...	...	20
Hydrochloric acid (12·6HCl), ,,	...	...	...	...	10	10	...
Water, ... ,,	30	30	30	30	40	40	30
Chlorate of potash solution, ,,	...	...	...	8·8	...	8·8	...
Perchlorate of potash, . ,,	...	...	6·2	...	6·2	...	...
Duration of action, . . min.	...	...	1·5	1·5	2	2	...
Temperature of mixture, . ° C.	...	...	17	17	16·5	16·5	...
Permanganate, . . . c.c.	11·2	11·3	11·3	11·0	11·3	11·2	11·2

In experiments 11 and 13 the chlorate of potash solution used was not that described above, which is used for all the following experiments, but a somewhat weaker one, of which 14·2 c.c. were required to oxidise 0·1 gramme of iron. It will be seen that the only case which shows any decomposition is No. 11, where 11·0 instead of 11·2 c.c. permanganate have been used. Hence at ordinary temperatures the action of chlorate of potash in dilute acid solutions does not necessarily begin instantaneously.

In Table III. will be found the results of experiments on the oxidising effects of solutions of perchlorate, chlorate, and nitrate of potash acting on ferrous sulphate solution (*c*) for different lengths of time at ordinary temperatures. The mixture consisted in each case of 10 c.c. ferrous sulphate solution (*c*), 20 c.c. H_2SO_4, 30 c.c. water, and 10 c.c. of one of the oxidising solutions.

TABLE III.

Duration.	Temperature.	Cub. cents. Permanganate.				Chlorate decomposed per cent.
		Perchlorate.	Chlorate.	Nitrate.	Blank.	
Hours.	° C.					
1	18 to 19	17·8	12·5	18·0	18·0	30·2
23½	14 to 19	17·9	2·25	17·8	17·8	87·4
51	9 to 16	17·7	1·2	17·8	17·8	93·2
168	9 to 18	17·7	0·3	17·75	17·75	98·3

From these results it will be seen that ferrous sulphate in sulphuric acid solution, containing 0·1 gramme iron in 60 c.c. is stable at ordinary temperatures in presence of the quantity of nitrate or perchlorate of potash necessary for the complete oxidation of the iron. In the case of chlorate the oxidation goes on at such a rate that in one hour 30·2 per cent., and in seven days 98·3 per cent. of the iron has been oxidised. In connection with these experiments it was observed that a clear solution of bleaching powder saturated in the cold, oxidises ferrous sulphate at once and completely in the cold; and that bromine water resembles chlorate of potash in requiring time, and being accelerated by a high temperature.

The observations in Table IV. were made with a view to gain a closer insight into the behaviour of chlorate of potash solution at ordinary temperatures. The mixture exposed was in all cases 10 c.c. ferrous sulphate (*c*), 10 c.c. chlorate solution, 20 c.c. H_2SO_4, and 30 c.c. water. In three blank experiments without chlorate 17·6 c.c. permanganate were used.

TABLE IV.

Temperature of solution, ° C.	13·5	13·8	14·0	14·2	14·9	15·0	15·1	15·2
Duration of action . min.	16·5	33	49·5	66	99	132	165	198
Permanganate used, . c.c.	16·35	15·2	14·25	13·35	11·5	10·4	9·35	8·5
Per cent. chlorate used, . .	7·10	13·64	19·03	24·15	34·66	40·91	46·88	51·70

It will be seen that during this series of observations the temperature rose from 13·5° C. to 15·2° C., in consequence the decomposition has gone on during the short intervals more slowly, and during the long intervals more quickly than it would have done at a mean constant temperature.

In Table V. are given the results of observations on the action of nitrate and perchlorate solutions at higher temperatures. The composition of the solutions was as before, 10 c.c. ferrous sulphate (*c*), 20 c.c. H_2SO_4, 30 c.c. water, and 10 c.c. of perchlorate or nitrate of potash. They were heated for five or six minutes to two intermediate temperatures, and also boiled for a like time. In three blank experiments made during the series 17·55, 17·50, and 17·55 c.c. permanganate were used.

TABLE V.

Oxidising agent.	Perchlorate.			Nitrate.		
Temperature, . ° C.	46	81	boiling	56	84	boiling
Duration in minutes, .	5	5	6	5	5	5
Permanganate used, c.c.	17·5	17·6	17·55	17·45	17·6	17·55

From these results it will be seen, and in the case of nitrate at least with surprise, that even boiling for five minutes has had no effect in bringing about a reaction between the oxidising agent and the ferrous salt. In the case of chlorate it is otherwise. In the following three experiments the chlorate was allowed to act for five minutes. In a blank experiment 17·6 c.c. permanganate were used.

TABLE VI.

Temperature, . . . °C.	28	47	70
Permanganate used . . .	15·95	11·9	3·8
Chlorate used, per cent. . .	9·2	33·5	77·1

The effect of dilution on the rate of action will be apparent from Table VII. For each experiment 10 c.c. of ferrous sulphate (*a*) were allowed to react on 10 c.c. chlorate of potash along with 10 c.c. H_2SO_4, and different quantities of water, which will be apparent from the figures giving the total volume of the solution. After standing exactly half an hour they were titrated with permanganate. In the last four experiments in this table the sulphuric acid used was formed by diluting 1 part of oil of vitriol with 4 parts of water (both by weight); it may therefore be written $2H_2SO_4$, as there are two gramme-molecules in the litre. Three blank experiments gave 17·6 as the permanganate equivalent to the 10 c.c. ferrous sulphate.

TABLE VII.

Temperature, . °C.	18	17	16·7	12·8	12·7	12·7	12·8
Volume of solution, c.c.	40	80	120	30	60	90	120
Permanganate used, ,,	10·95	15·35	16·4	9·2	14·5	16·15	16·8
Chlorate used, per cent.,	37·7	12·7	6·8	47·8	17·8	8·5	4·8

I hope shortly to be in possession of more extensive experimental data, and to discuss them in a future paper.

7. On some Space-Loci. By Professor Tait.

(*Abstract.*)

The class of problems treated is one to which considerable attention has been paid of late, as for instance by Glaisher and others in this country, and by Mannheim, &c., abroad.

Two years ago (Proc. 1879, p. 200), in connection with Minding's Theorem, I investigated the space-locus of the feet of perpendiculars from the origin on the rays of a complex. These were found to fill the space bounded by the two sheets of the reciprocal of a Fresnel's wave-surface. The method I employed is capable of very extended application in the same direction, and the following general process is applicable to all the problems I have seen treated by the authors above referred to.

Let
$$\rho = \alpha + x\beta,$$
where
$$T\beta = 1,$$
be any ray of a complex; and let the scalar condition determining a point on it be
$$F(\rho) = 0.$$
This determines x in terms of α, β; and the number of independent scalar variables is reduced by two additional data, such as a relation between α and β (*i.e.*, $S.\alpha\beta = 0$), or a relation among the values of x (*i.e.*, $f(x_1, x_2, \ldots .) = 0$), according to the nature of the complex.

We have now to make $T\alpha$ a maximum or minimum, subject to the additional condition that
$$U\alpha = \text{constant}.$$
This gives rise to three scalar equations which may be written
$$S.\dot{\beta}\beta = 0,$$
$$S.\dot{\beta}\nu_1 = 0,$$
$$S.\dot{\beta}\nu_2 = 0,$$
or, finally,
$$S.\beta\nu_1\nu_2 = 0,$$
i.e., β is coplanar with ν_1, ν_2, which are usually normals to surfaces at the points of intersection with a ray of the complex. This is one of the chief points of Mannheim's treatment of the subject. When, as is often the case, the surface on which the complex is made to depend is an ellipsoid
$$S.\rho\phi\rho = 1;$$
the last written equation usually takes the form
$$\beta + y\phi\beta + z\alpha = 0,$$
or
$$\beta = -z(y\phi + 1)^{-1}\alpha,$$
whence
$$-1 = z^2 S.\alpha(y\phi + 1)^{-2}\alpha.$$
In this equation y and z depend upon $T\alpha$, so that the space-locus is closely connected with Fresnel's wave-surface, whose equation is capable of a very remarkable series of transformations, depending on the properties of the expression
$$S.\alpha(\phi + g)^{-1}\alpha.$$

Monday, 4th April 1881.

PROFESSOR BALFOUR in the Chair.

The following Communications were read:—

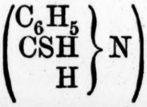
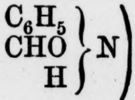
1. On the Pressure-Errors of the "Challenger" Thermometers.

By Professor Tait.

(This paper will appear in the *Challenger Reports.*)

2. The Action of Heat on Thioformanilid.

By W. W. J. Nicol, M.A.

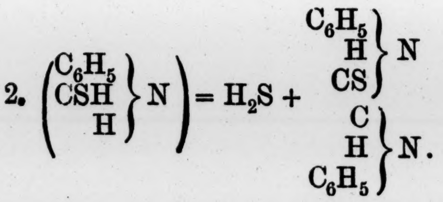
While at work during the past session in the Berlin Laboratory, it was suggested to me by Professor Hofmann, that I should examine the behaviour of thioformanilid ( $\left.\begin{matrix}C_6H_5\\CSH\\H\end{matrix}\right\}N$) when submitted to various degrees of heat. The thioformanilid employed was prepared by heating formanilid (phenylformamid  $\left.\begin{matrix}C_6H_5\\CHO\\H\end{matrix}\right\}N$) with pentasulphide of phosphorus, the resulting mass was treated with dilute caustic soda, and the alkaline solution of thioformanilid thus obtained was mixed with excess of hydrochloric acid, when impure thioformanilid separated out; this was purified by crystallisation from hot dilute alcohol. The crystals thus prepared melted at 137°–138° C., the melting-point of pure thioformanilid being 137·5° C. (Hofmann).

Fifteen to twenty grains of thioformanilid were heated in a sealed tube to 180° C. for from six to seven hours. At the end of this time the tube was found to contain a confused mass of crystals, with a small quantity of a colourless liquid, and on opening the tube a considerable amount of sulphuretted hydrogen was evolved. The solid mass dissolved readily in alcohol, leaving no residue, but it was impossible to obtain crystals from this solution. When, however, the hot alcoholic solution was mixed with just sufficient hot water to render it opalescent, crystals were readily formed on cooling; the greater proportion of these were scales or plates, mixed with some needles of unaltered thioformanilid. A second crystallisation gave a crop of pure crystals which were washed with 60% alcohol and dried in vacuo. Their melting-point is slightly higher than that of thioformanilid, 140° C., and, as is also the case with that body, the point of solidification is very much lower. They are nearly insoluble in hot benzol, and are practically unattacked by hot caustic soda, which first dissolves and then decomposes thioformanilid with formation of aniline, sodium formiate and sulphydrate. An analysis of this body, dried at 90° C., gave results agreeing very closely with the numbers calculated for the body formed from two molecules of thioformanilid by the abstraction of one molecule of sulphuretted hydrogen. This would have the empiric formula, $C_{14}H_{12}SN_2$.

	Found mean.	$C_{14}H_{12}SN_2$.
Carbon,	69·7	70·0
Hydrogen,	5·3	5·0
Nitrogen,	11·6	11·7
Sulphur (by dif.),	13·4	13·3
	100·0	100·0

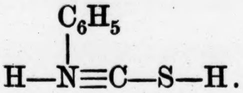
The platinum salt, which, however, was non-crystalline, contained 29·9% platinum, $C_{14}H_{12}SN_2(HCl)_2PtCl_4$ contains 29·8% platinum.

The above analyses settle the composition of this body, and the equation for the decomposition is simple enough.

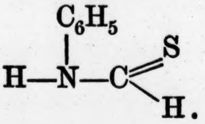


$$2\left(\left.\begin{array}{r}C_6H_5\\CSH\\H\end{array}\right\}N\right) = H_2S + \begin{array}{l}\left.\begin{array}{r}C_6H_5\\H\\CS\end{array}\right\}N\\\left.\begin{array}{r}C\\H\\C_6H_5\end{array}\right\}N.\end{array}$$

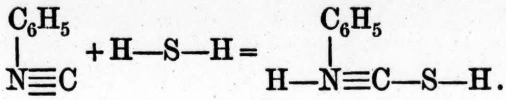
Its constitution, however, is uncertain, owing to the uncertainty with regard to the constitution of thioformanilid. This latter body may be written in either of two ways, according as it is supposed to contain the mercaptan group $(CSH)^{III}$ or the sulphaldehyde group $(CHS)^{I}$.



$$\begin{array}{c}C_6H_5\\|\\H-N\equiv C-S-H.\end{array}$$

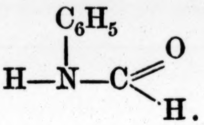


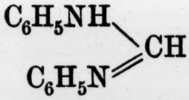
Hofmann, in his paper[*] describing the preparation of thioformanilid, assigns to it the former of these formulæ, and this view of its constitution is borne out by its solubility in alkalies, and by its formation from isocyanide of phenyl by the addition of H_2S.[†]



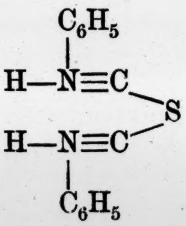
$$\begin{array}{l}C_6H_5\\|\\N\equiv C\end{array} + H-S-H = \begin{array}{c}C_6H_5\\|\\H-N\equiv C-S-H.\end{array}$$

The second view of its constitution is supported by its preparation from formanilid and pentasulphide of phosphorus, formanilid being admitted to have the constitutional formula.

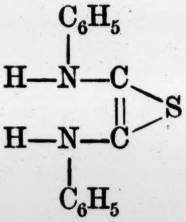


The third method for the preparation of thioformanilid, that from sulphuretted hydrogen and diphenylmethenyldiamine[‡]  also seems to support the latter view.

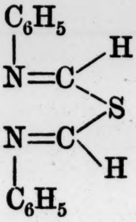
The constitutional formula of this body may therefore be written either



or



or



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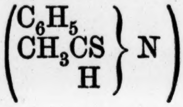
[*] Hofmann, "Ber. Deut. Chem. Ges.," 1878, p. 338.

[†] Hofmann, "Ber. Deut. Chem. Ges.," x. 1095.

[‡] Bernthsen, "Ber. Deut. Chem. Ges.," x. 1241.

according to the view taken of the constitution of thioformanilid, and the position of the abstracted hydrogen atoms. I hope soon to be able to throw additional light on this point by additional experiments on thiacetanilid  $\left(\left.\begin{matrix}C_6H_5\\CH_3CS\\H\end{matrix}\right\}N\right)$ regarding the constitution of which there is no doubt.

3. On the Classification of Statistics. Part II.
By Mr P. Geddes.

BUSINESS.

The following candidates were balloted for, and declared duly elected Fellows of the Society:—D. J. Hamilton, M.B., F.R.C.S.E.; Dr Leonard Dobbin.

Monday, 18th April 1881.

SIR WILLIAM THOMSON, Hon. Vice-President,
in the Chair.

The following Communications were read:—

1. On Galvanic Polarisation. By Professor Helmholtz.

In 1872 I wrote a paper on galvanic currents, which continue for a long time in an electrolytic cell, under the influence of an electro-motive force, too feeble to effect electrolytic decomposition. I tried at that time to prove that the long duration of these currents was caused by oxygen dissolved in the water of the electrolyte, combining with the hydrogen, which is carried by the electrolytic motion to the cathode. So the oxygen, which existed formerly near the surface of the cathode, is taken away, and instead of it the same amount of oxygen is liberated at the anode. This can return by diffusion to the cathode, and so the same action can go on without end. It appears as a current producing no electrolytic action. I called it "Electrolytic convection."

My experiments, published at that time, were performed with an electrolytic cell, from which the air was removed by a mercury air-pump; but I did not succeed in getting it absolutely free of air, because the lubricating grease of the stopcocks allowed some air to get in during the long time through which it was necessary to continue the experiments.

Lately I have had better results with a cell hermetically sealed, containing acidulated water and a vacuum, filled of course with vapour of water. Three electrodes enter the cell; two of them platinum wires, the third a thin platinum wire, to which a spiral of palladium is fixed. Before closing the glass tube through which I had introduced the liquid, I removed the atmospheric air left in the cell by means of a water air-pump, and sent an electric current through the cell, so that oxygen was evolved at the two platinum wires, and all the hydrogen was occluded in the palladium. Then I closed the tube with the blow-pipe. The traces of oxygen remaining in the interior of the cell combined again slowly with the hydrogen of the palladium, and even if I evolved new quantities of electrolytic gases in the interior of the closed cell, they could be removed again by the electro-motive force of a Daniell's cell, driving the oxygen to the platinum wires and the hydrogen to the palladium. On the contrary, I may charge the two platinum wires with hydrogen, if I connect them for a short time with the palladium wire.

If the platinum wires be freed from all hydrogen, a feeble electro-motive force, of about 0·01 to 0·001 Daniell, gives only a very short deflection; then the galvanometer returns to zero. Removing the electro-motive force without breaking the circuit, I saw an opposite deflection, equal in magnitude to the former and of the same duration. I have measured the capacity of the two platinum surfaces considered as condensers. They behaved like two condensers, the two electric strata of which were separated by an interval of a ten millionth part of a millimeter. This is a capacity smaller than that found by *Kohlrausch* ($\frac{1}{15,000,000}$ mm. distance) and other observers. But I found that the capacity appeared to be much greater, if only a small quantity of hydrogen were carried by an electric current to the platinum. The same was the case if the wires were newly polarized with oxygen, but this latter modification vanished some hours after the battery had been taken away. In these latter cases a part of the current produced by the external electro-motive force must be considered as caused by electrolytic convection, and this part vanishes very slowly and never completely.

The quantity of electricity which was carried to the platinum electrodes when they were free of hydrogen, was exactly proportional to the electro-motive force applied to the cell, down to forces of $\frac{1}{1000}$ Daniell. From this is to be inferred that no kind of chemical or molecular force exists in the interior of the electrolytic fluid, which is able to prevent the ions of the electrolyte from moving about in the interior of the fluid, till they have got the distribution required for the equilibrium of the electric forces. For if such a force existed, we ought to find an inferior limit to the electro-motive forces, which are able to charge the electrodes like a condenser.

2. On the Average Pressure due to Impulse of Vortex Rings on a Solid. By Sir William Thomson.

3. On the Crushing of Glass by Pressure.

By Professor Tait.

In the course of my examination of the "Challenger" thermometers, I was once surprised by a sudden bell-like vibration of the massive iron cylinder (nine inches thick) in which the apparatus to be tested was enclosed. This was due to the giving way of the protecting-sheath of one of the thermometers, at a pressure of a little over four tons weight on the square inch. When the pressure was let off, the bulb of the thermometer was found to have been crushed to an almost impalpable powder. I then determined to make a set of experiments with the view of finding under what amount of distortion glass gives way. For this purpose I employed the smaller compression apparatus which I have already described to the Society. Its capacity is about ten cubic inches only, so that a couple of strokes of the pump produce a pressure of three to four tons weight.

I procured a number of pieces of glass tubing, with very varied ratios of external and internal diameter. These were all drawn from the same melting in the Leith Glass-works, and consisted of ordinary lead-glass.

By means of a small telescope, with a micrometer scale in the eye end, the ratio of the internal and external radii was measured for each end of each tube. The tube was then cut into five, seven, or nine lengths, and these were numbered (in order) by marked slips of paper inserted into them. They were then carefully and strongly sealed at each end, a small quantity of shot being put into each to make them sink in water.

By means of the external gauge I have already described to the Society, the pressure at which Nos. 1, 3, 5, &c., gave way was measured, and it was found that when the tube from which they were cut was stronger at one end than at the other, the breaking pressures for the separate pieces were in the proper *order* of magnitude. The results were, as was to be expected, not very accordant; but, as a fair average result, the common lead glass gives way when subjected to a shear of about $1 \pm \frac{1}{230}$ (combined with a compression of about $\frac{1}{600}$ in every direction). Hence a very thick tube of such glass will not resist more than about 14 tons weight on the square inch of external pressure.

The formulæ from which this was calculated are given in my paper of May 17, 1880 (Proc., vol. x. p. 572). They give, for a pressure of one ton weight per square inch, the following for the innermost layer of a cylindrical tube of external and internal radii a_1 and a_0 :—

$$\text{Radial compression} = \frac{a_1^2}{a_1^2 - a_0^2}\left(\frac{1}{8100} - \frac{1}{3200}\right),$$

$$\text{Tangential} = \frac{a_1^2}{a_1^2 - a_0^2}\left(\frac{1}{8100} + \frac{1}{3200}\right),$$

$$\text{Longitudinal} = \frac{a_1^2}{a_1^2 - a_0^2}\,\frac{1}{8100}.$$

The first terms of these expressions indicate a uniform compression, the other terms the crushing shear. [It is curious to note that this compression is *less* (for the same pressure) in a solid rod ($a_0 = 0$) where there is no shear, than in a tube.]

The walls of these tubes, when they gave way, were crushed into fine powder, which gave a milky appearance to the water in the compression apparatus. But the fragments of the ends were larger, and gave much annoyance by preventing the valves of the apparatus from closing. To remedy this inconvenience I enclosed the glass tube in a tube of stout brass, closed at the bottom only, but was surprised to find that it was crushed almost flat on the first trial. This was evidently due to the fact that water is compressible, and therefore the relaxation of pressure (produced by the breaking of the glass tube) takes time to travel from the inside to the outside of the brass tube; so that for about $\frac{1}{10000}$th of a second that tube was exposed to a pressure of four or five tons weight per square inch on its outer surface, and no pressure on the inner. The impulsive pressure on the bottom of the tube projected it upwards, so that it stuck in the tallow which fills the hollow of the steel-plug. Even a piece of gun-barrel, which I substituted for the brass tube, was cracked, and an iron disc, tightly screwed into the bottom of it to close it, was blown in. I have since used a portion of a thicker gun-barrel, and have had the end welded in. But I feel sure that an impulsive pressure of ten or twelve tons weight would seriously damage even this. These remarks seem to be of some interest on several grounds, for they not only explain the crushing of the open copper cases of those of the "Challenger" thermometers which gave way at the bottom of the sea, but they also give a hint explanatory of the very remarkable effects of dynamite and other explosives when fired in the open air. [It is easy to see that, *ceteris paribus*, the effects of this impulsive pressure will be greater in a large apparatus than in a small one.]

4. On the Cause of the Sounds produced in the Microphone Receiver. By Professor James Blyth.

In the microphone, or loose contact receiver, we have two or more small blocks of carbon resting lightly against each other, through which the interrupted current from the transmitter is passed. At the points of contact, a strong heating and cooling effect must take place every time the current is interrupted or otherwise varied. This heating and cooling will cause corresponding expansions and contractions of the air or other medium surrounding the points. These produce undulations in the medium, which, striking against the sides of the containing vessel, set them also into a state of vibration, and so reproduce the sounds of the transmitter. To test the truth of this explanation, I have made the following experiments :—

A cylindrical tin box, about four inches in diameter and two inches deep, with a tight-fitting lid, was provided. In the sides of the box three openings for corks were made—two being at the opposite ends of a diameter, and the third in a line at right angles to this diameter. Through the corks in the two opposite openings stout copper wires were passed, connected inside by a spiral of fine iron, or platinum wire. By this means the spiral was completely enclosed in the box, and the interrupted current from the transmitter could be easily sent through it. Through the third opening the box could be filled with water, or with any gas or vapour on which it was desirable to make experiments. The transmitter employed was either a tuning-fork interruptor, which vibrated 256 times per second, or the violin-microphone, and the battery power employed varied from ten to fifteen Groves's cells. When the interrupted current from the fork was sent through the spiral of fine wire, it was seen, on looking through the upper opening, to glow with a beautifully varied glow, and on applying the ear to the end of the box, the sound of the fork was most distinctly heard. The box was then completely filled with water, and still the sound was heard almost as distinctly as before, accompanied, however, with a hissing noise. The electrodes carrying the spiral of fine wire were next removed, and replaced by two gutta-percha covered copper wires, so fixed as to leave a distance, inside the box, of about half an inch between their uncovered ends. The box was then completely filled with mercury, and the interrupted current sent through it. The current was thus made suddenly to heat and cool the line of mercury lying between the exposed ends of the electrodes, and this heating and cooling was distinctly recognised by the sounds heard when the ear was applied to the end of the box. The sounds, however, were not musical, although the tuning-fork was used, but consisted merely of dull thuds, arising, as it seemed from slow waves set up in the mass of the mercury.

It struck me that, in this experiment, the action might be due partly to the repulsion between the end of the wire and the mercury produced by the self-induction of the current. To test this, I had a telephone constructed so as to isolate this effect, and, if possible, bring it only into view. It consists of a short vertical wooden tube, containing a column of mercury,—the bore being about half an inch in diameter. On the top of the tube, which terminates in a circular enlargement, an ordinary ferrotype plate is placed, which has a copper wire soldered to its centre, dipping vertically downwards for a short distance into the mercury in the tube. The current is led upwards through the mercury column to the copper wire, and thence to the ferrotype plate, which is in metallic connection with one of the poles of the battery. By this arrangement any action from self-induction which takes place will be of the nature of a thrust vertically upwards upon the copper wire, and through it upon the ferrotype plate, which will, in consequence, be made to vibrate in sympathy with the interruptions of the current in the circuit. When the tuning-fork was used, I was able to hear the sounds from it faintly, but still distinctly enough to leave no doubt of the effect.

I next determined to try the effect of exhausting the air from the space surrounding the glowing spiral of fine wire. For this purpose I employed the apparatus known as the *electric egg*. A spiral of fine platinum wire was placed vertically between the two terminals, and I first made sure of hearing the sound of the fork by applying my ear to the outside of the egg. The air was then gradually exhausted, and the sound decreased perceptibly till it became almost inaudible. To get the effect of a more perfect exhaustion, I next employed one of Mr Swan's electric lamps. When the interrupted current from the fork was sent through the lamp, no trace of sound could be heard by applying the ear to the side of it, although the variation of the glow in the carbon fibre from dull red to a very bright red, approaching to white, was most beautifully seen to be produced by the variation of the current. This at once shows that the presence of air or some other medium is necessary, in order that its expansion and contraction, produced by the heating and cooling of the wire, may affect the sides of the vessel, and so give out the sounds.

Monday, 2d May 1881.

PROFESSOR MACLAGAN, Vice-President, in the Chair.

The following Communications were read:—

1. On the Classification of Statistics. Part III.—Results.

By Mr Geddes.

2. On the Motion of a Storm in an Easterly Direction being only possible as a Circular Atmospheric Wave.

By Robert Tennent.

It is here intended to show how a storm with a diameter of several hundred miles, and with a comparatively low vertical height, can move and only in contact with the resisting surface of the ground, but not on a frictionless surface. Exceptional cases are all here received owing to the complexity of the subject, and also to the comparatively few conclusions which have been arrived at in the millions of observations which have taken place. Let this storm be supposed to be inaugurated in the United States, and be described as being a vast mass of rarefied air enclosed within its surrounding isobarics. In this form, as is well known, it does not cross the Atlantic and to the British Isles; it only alters its position in the form of a circular-atmospheric wave, and by the "Curve of Outward Propagation" in front, described in the paper of 1877–78, page 574, and which is accepted by a well-known continental meteorologist. As shown by the Rev. W. Clement Ley, cirrus clouds aloft move in front and from low to high pressure. This also takes place with the Curve, which, by the alteration of the position of the atmosphere aloft, may thus probably produce these clouds. Opening out of a storm in this way in front, of course fills up in the rear. To enable this to take place, it is of course accompanied by a spiral inflow to its low centre, and with the important and necessary motive force of the central ascending current, on a resisting but not on a frictionless surface, as exhibited in the diagram of the ascending balloon. Spiral inflow differs in its direction, and also with its source of supply in the different segments; how can a depression then remain stationary? It is shown to move in the direction of the less copious source of supply of the lowest gradients, and of the widest isobars, accompanied of course by high pressure and by steep gradients on the south segment, which there necessarily aids the velocity of the west winds, and in the direction of progress. Owing to the complexity and difficulty of the mode in which spiral inflow takes place, and also of the direction in which it is altered in the different segments, absolutely dependable observations are not to be found. For facility of explanation, it is here taken up in two points of view. First, in the mode of direct inflow which only occasionally takes place; and, secondly, also in the very important mode in which it circulates round the low centre, but which, as exhibited on the surface, takes place in a very different manner on the different segments. It is only by circulation that the structural form of an aerial cavity can possibly be maintained. This circulation, which is in a direction against that of the hands of a watch, is for facility here supposed to take place at the same rate of speed as that of progress, and in an easterly direction. On the north segment, east winds, which here circulate round the low centre and in a direction opposite to that of progress, are necessarily calmed, though only with reference to the surface. On the south segment, where west winds both circulate and blow in the direction of progress and with a consequent amount of velocity, they must necessarily there be accompanied by high pressure, while east winds only require low pressure, and which must also be found in front. The velocity of east and west winds are here supposed to circulate at the same rate of speed round the low centre; with reference to the usual surface observations, they are not here comparable. East winds may thus be regarded as being those of space. It is owing to this, as shown, that there is to be found the remarkable difference in the alteration of the position of the north and south segments in the form of a circular atmospheric wave. This is fully illustrated in the diagrams of the paper, and is here shown how the calm north segment of east winds can only alter its position, and by so doing exhibit the necessary progressive movement.

In a letter received from Ballot, he mentions his great difficulty in ascertaining the comparative velocity of east winds with reference to their gradients as compared with those of other winds. As above described, how can the effect of the gradients of the different winds not differ with each other? Moreover, as shown in a former paper, the barometer does not always and actually represent the real weight of the atmosphere aloft; how can it not also do so in a rapidly ascending and in a descending current? Under such circumstances the isobarics and the gradients cannot be absolutely correct, especially in those which are found at some distance from the low centre. To ascertain the correctness of the barometer much importance must be attached to it, which is accepted by well-known men, and is also opposed by others. It ought therefore to be fully discussed, and suitable observations to be received.

3. On Chemical Nomenclature and Notation. By Professor Crum Brown.

Monday, 16th May 1881.

Professor FLEEMING JENKIN, Vice-President, in the Chair.

The following Communications were read:—

1. Note on a *Phoronis* dredged in H.M.S. 'Challenger,'

By W. C. M'Intosh.

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This form, which in many respects is a most interesting intermediate type, was dredged at Station 212, south of the Philippine Islands, on the 30th January 1875, in lat. 6° 55′ N., long. 122° 51′ E., at a depth of 10–20 fathoms, on a sandy bottom. The total length is about 52 mm., with a variable diameter of about 2 mm. at the blackish anterior region, and 4 or 5 mm. at the posterior. The tentacular or branchial region has a length of 6 or 7 mm.

The body is elongate, smoothly rounded to the naked eye, and generally thrown into several constrictions and enlargements as in *Phascolosoma*, or in certain examples of *Cerianthus* and *Edwardsia*, the bulbous posterior end (devoid of all transverse wrinkles) of many making the resemblance to the latter all the more striking. On the other hand, the double branchial fan and general appearance approach the contour of the Eriographididæ and Sabellidæ amongst the Annelids. The anterior third of the body, which is tinted of a blackish hue with a slight metallic lustre fading posteriorly, is most minutely marked by fine transverse lines, as in the massive muscular proboscis of *Lepidonotus* and *Aphrodita.* These circular striæ are much finer in front, and gradually widen towards the posterior part of the coloured or anterior region, which in almost all the specimens is firmly contracted—from the peculiar structure of the body-wall. The dorsal is distinguished from the ventral surface by a longitudinal furrow (on each side of the median line), which cuts off a ridge or segment overlying the rectum. In many, the body gradually dilates toward the end of the anterior region, and an enlarged pale "bladdery" part often occurs—marked by a close series of longitudinal bands—crossed externally by fine transverse striæ, so that the region has a tesselated appearance. Such an aspect, of course, diverges very much from the eight longitudinal bands in *Edwardsia* and *Cerianthus,* though, as will afterwards be noticed, there is a certain structural resemblance between the muscles of the diverse groups. Even in the somewhat narrower region of the *Phoronis,* behind the latter part, traces of these longitudinal bands (the muscular fasciculi) are visible. Finally, the body ends in a more or less clavate or bulbous region, which is generally devoid of such markings.

The contracted anterior region of the body, after the muscles are fully formed, presents externally in transverse sections the chitinous cuticula, then the hypoderm, which even in fine sections is almost opaque from the deposit of blackish pigment. Beneath is a translucent and probably elastic basement-tissue of considerable thickness. The circular muscular coat, which immediately follows, is not much developed at the commencement of the region, the radiating series of fibres which pass from the body-wall between the pennate portions of the next coat and the œsophagus, apparently performing the chief functions necessary. The next or longitudinal coat is regularly arranged in bands, which in transverse section present a most regularly pennate appearance—a pair of dense fasciculi, with a somewhat fan-shaped series of striæ, occurring at the base (externally), within which the arborescent or complexly pennate fibres project. It is interesting to notice a kind of gradation between the lax pennate arrangement of the longitudinal muscular bands in *Peachia,* the coarse pennate system in *Phoronis,* and the more finished pennate plan of the muscles in the Eriographididæ.

Towards the posterior part of the foregoing region, the circular muscular coat becomes much thicker, while the radiating fibres diminish, and become of secondary importance in the greatly enlarged visceral area. In the succeeding part of the body, indeed, the muscular layers diminish in proportionate bulk, and as we approach the posterior end the pennate arrangement of the longitudinal fibres disappears, and the latter form a comparatively thin layer under the basement tissue—the circular coat being internal. The termination of the body is thus ensheathed by uniform layers of longitudinal and circular fibres.

The tentacles or branchiæ arise from the slightly-enlarged cephalic end by a somewhat firm basal web, which is entire ventrally, but is widely split dorsally, so as to present the aspect of a double fan, as in the Sabellidæ. Indeed, viewed from this surface, each fan or volution is supported on its own basis, which, moreover, is oblique—elevated in the centre, and sloping downward and outward externally. The basal web remains entire for about a third of the total length of the tentacular arrangement, and then breaks up into a multitude of simple, slightly-tapering filaments, which are pale throughout the greater part of their extent, but tinted of a dark brownish hue towards the tip. Externally, the surface of each is densely coated with cilia, which are somewhat longer toward the tip of the process. As ordinarily seen in the preparations, the branchial fan performs about three volutions. The skeletal elements of the apparatus commence on the sides of the anterior region of the body, as a series of simple longitudinal chitinous processes or rods—the dorsal and ventral regions at first being devoid of them. They lie just within the thick basement-membrane under the hypoderm. Proceeding distally (anteriorly) the chitinous skeleton becomes much more complex, from the fact that it develops tubes for the transmission of the circulatory fluid, extends round the whole circumference of the body except a limited region at the dorsal hiatus, and moreover splits into two or more rows. In the formation of the circulatory channels, the chitinous longitudinal processes would first seem to form a thin arch with two dilated pillars, and then a complete ring with much thinner walls. Before complete separation of the basal folds of the web occurs, the sections show a double row of these channels, one being on the outer edge of the volution and the other on the inner—a chitinous basement-layer separating the former row and its spongy vascular tissue from the latter. A line intersecting the coils would thus (before separation occurs) pass through four complete series of these channels, and in certain positions (involving the central volution) through six. At the base the inner row at the tip of the central coil is incomplete, but by and by the vessels form a continuous series round the edge. The structure of one of these double basal rows is as follows:—Externally is the cuticular layer, which, however, in the preparations does not seem to be well differentiated, since it forms only a definite boundary to the hypoderm. This feature is probably related to the branchial functions of the region. Within is a layer of hypoderm, which varies in thickness and colour according to the level of the section. Its structure agrees with the hypoderm of the body-wall, and accords with the same tissue in the Annelids and Nemerteans. Directly under it are the chitinous arches of the outer row of channels, which are incomplete internally, each debouching into a large vascular channel, which with connective tissue fills up the space between the outer row and the line of basement-tissue separating the two series. In transverse section the chitinous tissue shows the thickened sides formerly alluded to, and is often finely streaked, but the latter is probably only an optical peculiarity. Within the line of basement-tissue are the inner series of channels, which have complete walls (and the outer row would thus seem to be less developed at a given level inferiorly than the inner); and in transverse section present a noteworthy uniformity in appearance, viz., with a dumb-bell-shaped outline of the inner wall from the thickening of the median region or each side, while the lines of the outer wall laterally are nearly parellel. The outer and inner arches of the vessel are thinner. Only a slight quantity of connective tissue separates each chitinous channel from the septum (line of basement-tissue), while the other arch has a thick coat of hypoderm, which soon (as we proceed distally) becomes grouped in a series of fan-shaped masses. The inner surface of the chitinous channels is furnished with an epithelial lining; and since in section the arch next the septum generally has a rounded opaque mass of the circulating fluid, surmounted in many by a granular band as if from a fine wall, it is possible such represents the vessel (or at least a division or septum) with its contents. Proceeding distally, both sets of vessels (in the double rows) become complete, and the hypoderm covers both the outer and inner edges of each—the somewhat spongy vascular tissue having disappeared. Then each row becomes more individualized—having a thin layer of hypoderm on the inner or concave edge, and a prominent pennate mass (in section), several times thicker, on the outer. The rings are bound together only by a little connective tissue in the middle, and they soon become free,—the outer layer of hypoderm still remaining thicker, while that on the sides (where the densest portion of the chitinous ring exists) is less developed. When viewed longitudinally, this peculiar chitinous wall has a series of very bold and rather regular transverse folds or wrinkles; and an included vessel and its contents are apparent toward the tip.

The mouth opens at the bottom of the ventral (and outer) whorl of the branchial apparatus (which, as formerly mentioned, presents a continuous fold in this region)—the arrangement resembling a spacious funnel. The first part of the alimentary canal has its wall folded transversly in zig-zags, the next and longest region is mostly devoid of them, but they again become very well marked in front of the dilatation generally found at the posterior end of the body. The canal then turns forward along the dorsal aspect to terminate in the anus, on the ridge between the two dorsal branchial fans. The canal is fixed at its commencement by various fibres which pass from the lower curve to the ventral wall of the body, and by a strong band (with an elastic central portion) at each side to the lateral region of the body. The structure of the glandular lining of the canal agrees with that in the Annelids and their allies. Proceeding backward the œsophagus becomes fixed by the radiating muscular fibres passing from the body-wall between the pennate muscles throughout the greater part of the circumference. Dorsally, however, two strong oblique bands cut off a limited area for the rectum, and sling the former region by their attachment to its dorsal wall. These radiating bands would seem to perform an important function both in regard to the calibre of the alimentary canal, the vessels, and the body-wall. The canal retains similar connections throughout the anterior region, though it is more central in position as the body becomes constricted. In the less rigid region which succeeds, its wall is thinner, its cavity larger, and its connection with the body more lax. Its structure, however, remains the same. Food seldom occurs in the first region of the alimentary canal, but in the dilated posterior part and after it turns round to proceed forward to the anterior end, the granular contents abound with Foraminifera, Radiolarians, diatomes, sponge spicules, and other organic debris. For the most part the intestine is kept *in situ* on the dorsal aspect of the first region of the canal by the oblique fibres passing from the dorsal wall of the body to the upper arch of the digestive tube, and which form, in the contracted region anteriorly, the special chamber formerly alluded to. The terminal portion is generally much contracted—except just at the anus.

The chief point observable in regard to the circulatory organs in the preparations is the presence of the great dorsal trunk, which extends almost, but not quite, from the posterior to the anterior end of the body along the dorsal arch of the first region of the alimentary canal. It gradually increases in size anteriorly, and in the first or contracted division of the body frequently presents a distinct septum, so that there would appear to be two channels, as in *Magelona.* A great lateral sinus occurs on each side, within the body-wall, at the termination of the dorsal trunk, but the exact mode of communication with the branchial vessels has not been observed. On each side of the main (or first) division of the alimentary canal is a considerable lateral trunk, and many large branches occur in the spaces between the body-wall and the former, being especially conspicuous in the interstices of the radiating fibres in the anterior region, and at the tip of the tail,—after the great dorsal and lateral trunks disappear. Many small vessels are apparent beneath the primary division of the alimentary canal, but no large trunk occurs in that position. None of the vessels are so small as to merit the name of capillaries, and all are loaded with large circular granular cells.

The generative apertures occur on each side of the anus, on a lateral elevation which appears just beyond the chitinous elements of the branchial apparatus. These apertures pass into a capacious chamber. The ova are developed in the posterior region of the body in racemose masses above the chief division of the alimentary canal. They occupy one side, while on the other is a bulky granular structure, which probably represents the male element. The ova occur in great numbers amongst the tentacles.

No observation of note was made on the nervous system.

The species forms a somewhat tough hyaline tube (evidently a secretion of the hypoderm) for itself in the sand, as in other forms having a similar habitat. In this coating sand-grains often occur, but they do not form a regular layer. Even the most translucent portions of the tube show many minute sponge spicules, diatomes, and fragments of silex.

This form of *Phoronis* deviates considerably from those previously described and from the ordinary Gephyreans. If, indeed, the branchial skeleton supporting the vessels were thrown in, and arranged at the side of the anterior region of the body, so that the water would enter by lateral slits, to aerate the circulating fluid, and the digestive canal enlarged and attached as a single tube to the body-wall, a form resembling *Balanoglossus* would be indicated. In both, as they exist, the food passes along the branchial apparatus before reaching the alimentary canal. The branchial arrangement and the flexure of the intestine also show certain analogies with the condition in the Polyzoa.

2. Additional Researches on the Structure of the *Palæoniscidæ* and *Platysomidæ*. By Dr R. H. Traquair.

3. Note on the Heating produced by Compression. By Professor Tait.

By the help of an iron-copper junction introduced into the smaller compression apparatus lately described to the Society, I have examined for a number of substances the rise of temperature produced by a sudden application of great pressure, and the corresponding fall of temperature when the pressure was very suddenly relaxed. The copper-iron circuit is, however, too little sensitive for very accurate measurements; as, from the nature of the apparatus, the wires must be so thin as to have considerable resistance, and the thermoelectric power of the combination is not large. I hope soon to have wires of cobalt, which (associated with iron) will give much larger indications on the galvanometer—so that I content myself for the present with a general statement of the results for cork and for vulcanized india-rubber, which are apparently typical of two classes of solids quite distinct from one another in their behaviour.

In the case of india-rubber the rise of temperature was found to be about 1°·3 F. for each ton-weight of pressure per square inch, up to four tons at least; and the fall in relaxation was almost exactly the same.

With cork each additional ton of pressure gave less rise of temperature than the preceding ton; and the fall on relaxation of pressure was, for one or two tons, only about half the rise. For higher pressures its ratio to the rise became greater. Two tons gave a rise of about 1°·6 F., and a fall of 0°·9 F.

With the same arrangement, the fall of temperature in water suddenly released from pressure at a temperature of 60° F. was found to be for

One	ton-weight per	square inch	0°·25 F.
Two	,,	,,	0′·56
Three	,,	,,	0°·93
ur	,,	,,	1°·35

These numbers give the averages of groups of fairly accordant results. I employed cooling exclusively in these experiments, because one of the valves of my pump was out of order, and the pressure could not be raised at a uniform rate. The effects obtained for successive tons of pressure are thus, roughly—0°·25, 0°·31, 0°·37, and 0·42 F.

If these results may be trusted, they probably indicate a lowering of the maximum density point of water by pressure. But they must be received with caution, because the galvanometer readings were all very small; and specially because the heating effect for one ton at 60° F. should be (by Thomson's formula) 0°·32 F., instead of 0°·25 F. as observed. Thomson's formula agrees very closely with the result for four tons pressure, so that it is possible that the cooling found for the lower pressures is subject to some error in defect.

I hope to settle this question, with more sensitive apparatus, during next winter by operating on water at about 39° F. In this case there should be no change of temperature unless the maximum density point is altered by pressure.

Monday, 6th June 1881.

PROFESSOR SIR WYVILLE THOMSON, Vice-President,
in the Chair.

The following Communications were read:—

1. On the Structure of the Skeleton of *Tubipora musica*, and on the Relation of the Genus *Tubipora* to *Syringopora*. By H. Alleyne Nicholson, M.D., D.Sc.

The object of the present communication is to briefly consider the general and minute structure of the corallum of the recent *Tubipora musica*, with special reference to the association of the genus *Tubipora* with the extinct genus *Syringopora*, as advocated by many modern naturalists. The method of inquiry that I have pursued in carrying out this investigation has been principally that of preparing similar thin and transparent sections of both the recent and the extinct types; and though there are special difficulties in the way of any examination of *Tubipora* by this method, I have been able to overcome these in a satisfactory manner, and to prepare a number of thin sections which answer all the requirements of the case. The results of my observations may be conveniently considered under the following heads:—

1. General structure of the corallum of *Tubipora*.
2. Minute structure of the corallum of *Tubipora*.
3. General structure of the corallum of *Syringopora*.
4. Minute structure of the corallum of *Syringopora*.
5. Supposed relationships between *Tubipora* and *Syringopora*.

1. *General structure of the corallum of Tubipora.*—The corallum of *Tubipora musica*, Linn., is one so familiar to naturalists that the peculiarities of its external form hardly need to be noticed. It consists of a number of fasciculate cylindrical tubes or thecæ, which are separated by small intervals from one another, and are upon the

whole parallel in their course, though they diverge to a greater or less extent as we pass from the fixed base to the surface of the colony. The entire corallum is of a bright red colour, the inner surfaces of the tubes being, however, usually lighter in colour than the outer surface. The cylindrical thecæ are bound together by horizontal calcareous floors (the so-called "external tabulæ") which are placed at varying distances apart in different specimens, but which are often disposed with considerable regularity, so as to form a series of concentric laminæ parallel with the upper surface of the colony. These horizontal floors unite the *outer* surfaces of the corallites; and, as pointed out by Professor Perceval Wright ("Ann. Nat. Hist.," ser. 4, vol. iii. p. 381), they are really produced by the coalescence of periodically-produced horizontal offshoots or extensions from the upper extremity of the tubes. Each offshoot consists of "a fold of the ectoderm, into which some of the endodermic layer is tucked," and by the calcification of the ectodermal layer the connecting-floors are produced. From the upper surfaces of the connecting-floors new corallites are budded forth, the upward expansion of the colony being due to the interpolation in this way of new tubes, as can be readily observed in the dead corallum. Horizontal sections through the connecting-floors show them to be traversed by a system of comparatively large-sized, branching, horizontal canals, which open at their extremities directly into the cavities of the polypes (fig. 1, B). Hence, if we open one of the thecæ at what we may call one of its "nodes"—that is to say, at a point where it is embraced by one of the connecting-floors, we find a ring of rounded apertures corresponding with the openings of the canals just spoken of (fig. 1, A). If, also, we examine the broken or cut edge of one of the connecting-floors, we observe the round and comparatively large orifices of the same canals as they traverse the interior of the floor. By means of this system of canals, the visceral chambers of the polypes composing a colony are placed in direct communication.

Though the connecting-floors of the colony are often spoken of as "external tabulæ," they have in reality nothing in common with the transverse plates or true "tabulæ" which intersect the visceral chambers of the corallites in such forms as *Favosites*. The only structures in *Tubipora* which can be even remotely compared with the proper tabulæ of *Favosites* or of *Syringopora* are to be found in a peculiar axial calcareous tube which may often be found in the centre of the visceral chambers of the corallites. When present, this tube (fig. 1, C) is never continuously developed throughout the entire length of the thecæ, but becomes dilated at every node (*i.e.*, at the levels corresponding with the external connecting-floors) into a funnel-shaped expansion, which fuses with the wall of the visceral chamber. The axial tube itself, so far as I have seen, is always open along its entire length, and is not crossed by any internal partitions; nor have I ever observed it to be in any way connected with the inner wall of the visceral chamber, except in the manner above indicated at the nodal points of the theca.

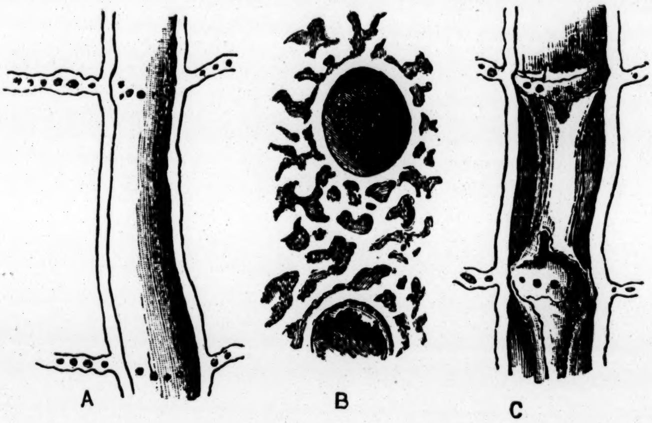


Fig. 1.—A, Part of a tube of *Tubipora musica*, Linn., divided longitudinally, showing the openings of the canal-system of the connecting-floors into the visceral chamber of the polype. B, Part of a horizontal section taken at the level of one of the connecting-floors, showing the canal-system of the connecting-floor. C, Part of a corallite of *Tubipora* divided longitudinally, showing the axial tube; in the lower portion of the figure the axial tube is laid open. All the figures are enlarged five times.

The above-mentioned axial tube seems in some specimens not to be developed in any of the corallites; at other times it is developed in many of the corallites of a colony, but not in others. Its existence was first pointed out by Mr Charles Stewart, F.L.S., in a paper which I unfortunately have not seen, by whom it was compared with the infundibuliform tabulæ and axial tube of *Syringopora*, a view which has been since adopted by Mr Moseley ("Voyage of H.M.S. Challenger," vol. ii. p. 125). I shall, however, subsequently give the reasons which lead me to believe that there is in reality insufficient ground for this comparison, and that the structures in question are morphologically different.

Finally, no traces of *septa*, either in the form of radiating lamellæ, or of vertically disposed spinules, or even as those plications of the wall which constitute the "pseudosepta" of *Heliopora*, have been detected in *Tubipora*.

2. *Minute structure of the skeleton of Tubipora.*—The microscopic structure of the corallum of *Tubipora* was first investigated by Kölliker ("Die Bindesubstanz der Cœlenteraten," p. 169, 1866), and very correctly described and figured. Professor Perceval Wright subsequently showed ("Ann. Nat. Hist.," ser. 4, vol. iii. p. 377), that the corallum is really formed of fusiform calcareous spicula, secreted by the ectoderm. Over the greater part of the theca these spicules become completely amalgamated with one another, so as to form a rigid case; but they remain loosely united or separate at the growing summits of the tubes, which are thus capable of withdrawal, during the retraction of the polypes, into the dense portion of the thecæ.

As the result of my own recent observations, carried on principally by means of thin transparent sections, I find that the entire calcareous skeleton of *Tubipora*, as pointed out by Kölliker, is permeated throughout by a system of minute, parallel, closely approximated tubules or canaliculi, which sometimes bifurcate, and occasionally anastomose. In the walls of the corallites themselves these tubuli (fig. 2 A), run at right angles to the inner and outer surfaces of the thecæ, opening both externally and internally by well-defined, rounded, and slightly dilated apertures (fig. 2, B), which can be readily observed by the examination of any fragment of the skeleton by means of a hand-lens or with a low power of the microscope. In the connecting-floors of the corallum, these tubuli are just as numerous and as well-developed as in the walls of the corallites, but here they run at right angles to the floor, either passing right through from the upper to the lower surface, or, more usually, opening internally into the large ramified canals which run in substance of the connecting-floors, and connect the visceral chambers of adjoining polypes. It follows from the above that the skeleton of *Tubipora* is in reality completely porous, the canaliculi by which it is penetrated, though minute, being quite large enough to be at once recognised by the use of a lens. The precise appearances presented by these canaliculi in thin slices, vary according to the direction in which the section has been taken. Thus, in sections taken transversely to the corallites (fig. 2, A), the tubuli are cut in the direction of their length; and the same is true of sections which are taken parallel to the corallites, but which lay open the visceral chambers of the latter. On the other hand, sections through the walls of the corallites taken parallel to the visceral chamber, and sections of the connecting-floors taken parallel to their upper or lower surfaces, cut the canaliculi at right angles, so that these appear as minute rounded or oval pores in the skeleton.

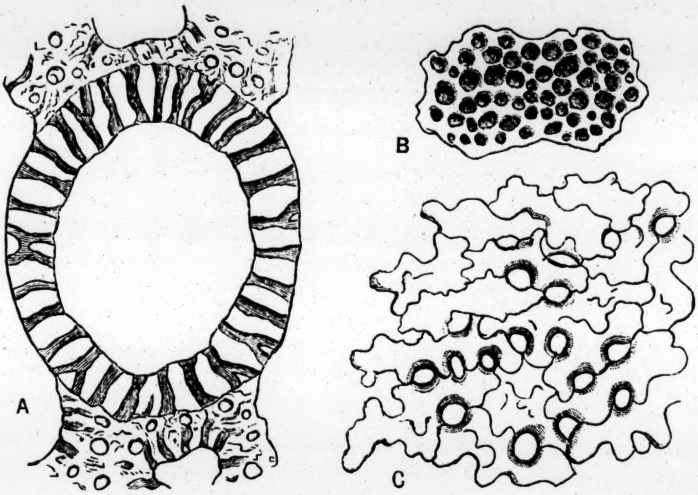


Fig. 2.—A, Transverse section of a corallite of *Tubipora musica*, Linn., taken at the level of one of the connecting-floors, enlarged twenty times, showing the tubuli of the wall. B, Portion of the surface of one of the connecting-floors, enlarged twenty times, showing the external openings of the tubuli of the skeleton. C, Fragment of the corallum of *Tubipora*, enlarged sixty times, showing the composition of the skeleton out of spicules. The figure is taken from a thin section which divides the tubuli of the skeleton at right angles.

The only other points connected with the minute structure of the skeleton, as revealed by thin sections are,—*firstly*, that it is easy to observe that the corallum is made up, as pointed out by Professor Perceval Wright, of a network of irregular fusiform spicules fused together (fig. 2, C), and *secondly*, that the marked red coloration of the skeleton resides chiefly in outer layer of the thecæ, the inner layer being nearly or quite white.

3. *General structure of the corallum of Syringopora.*—The genus *Syringopora*, Goldfuss, is one well known to naturalists, and its leading structural characters have been fully described by myself, ("Palæozoic Tabulate Corals," p. 207). As my object on the present occasion is simply to compare it with *Tubipora*, it will be unnecessary for me to do more than merely to draw attention to some of its more striking characters. The corallum in this genus is composed of fasciculate cylindrical calcareous tubes, which are placed at variable but slight intervals, and diverge slightly as the surface of the colony is approached, owing to the interpolation of new tubes. The visceral chambers of adjoining corallites are placed in direct connection by means of hollow, usually cylindrical, horizontal connecting-processes or tubes. These connecting-tubes are generally quite distinct from one another, and placed at tolerably regular and moderately distant intervals; but they are sometimes developed in successive whorls (as in *S. verticillata*, Goldf.), or the verticils may coalesce so as to give rise to almost uninterrupted horizontal connecting-floors (as in *S. tabulata*, Van Cleve). In this latter case, the mere external similarity of the corallum to that of *Tubipora* is very striking.

As regards the internal structure of the corallites of *Syringopora*, the visceral chamber of each tube is always subdivided by a remarkable and well developed system of tabulæ. These tabulæ are, typically, more or less infundibuliform, and they generally become invaginated in such a manner as to give rise to a central cylindrical tube, which occupies the axis of the visceral chamber (fig. 3, A). This axial tube, however, is in no respect a distinct or separate structure; but it is simply a central space left by the union of funnel-shaped tabulæ, and often broken up by the inward prolongation of these across its central cavity. In all the species of *Syringopora*, also, the corallites are provided with a well-developed system of *septa*. The septa (fig. 3, A and B), are entirely of the "Favositoid" type, or of the type of the septa *Porites*, being never lamellar, but having in all cases the form of slender spines arranged in vertical rows. They never extend more than a limited distance into the visceral chamber, but they vary in length, the larger species seeming to have about twenty rows of septal spines to each corallite.

4. *Minute structure of the corallum of Syringopora.*—The minute structure of the corallum of *Syringopora* is best studied in thin transverse sections of the corallites. When examined in such sections, the wall of the tubes is seen to be composed of dense indistinctly fibrous or granular sclerenchyma (fig. 3, A), and to be entirely devoid of any system of minute tubuli or canaliculi. The wall, in fact, is quite compact, and the visceral chambers of the polypes communicate with one another at no points except where the connecting-tubes of the colony may be developed. Very generally, the wall is distinctly composed of two layers, viz., the outer dense layer just spoken of and an internal layer of laminated

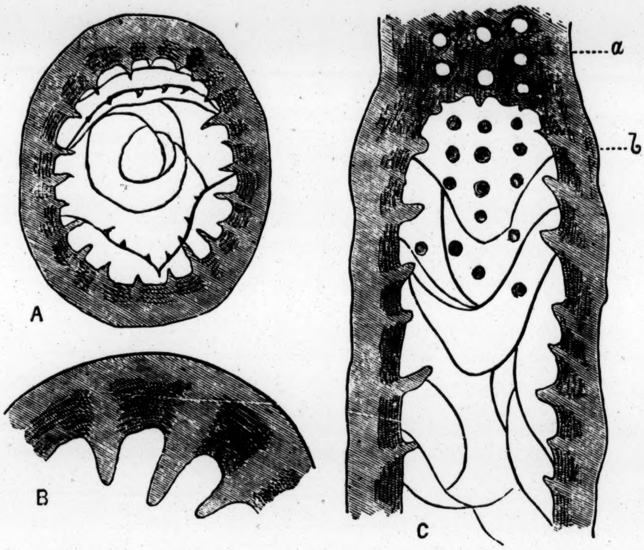


Fig. 3.—A, Transverse section of a corallite of *Syringopora reticulata*, Goldf., enlarged twelve times, showing the thick compact wall, the cut edges of the infundibuliform tabulæ, and the septal spines. B, Part of the wall of the same section enlarged still further, showing the composition of the wall out of an outer light layer and an inner dark layer, and the origin of the septal spines from the outer layer. C, Longitudinal section of a corallite of the same, enlarged twelve times. The section passes obliquely through the corallite, and consequently shows different appearances in different parts of its course. At *a* it cuts through the inner layer of the wall, and exhibits the divided bases of the septal spines as rows of light-coloured spots (these are unfortunately left quite white, as if they were actually foramina, whereas they should properly have been faintly shaded); at *b* it cuts through the visceral chamber near its periphery, and shows the cut ends of the septal spines as rows of dark spots; and below this point it becomes more nearly central, and shows the infundibuliform tabulæ. From the Carboniferous Limestone, Westmoreland.

or markedly fibrous sclerenchyma (fig. 3, A and B). When this is the case, the outer layer is usually of a conspicuously lighter colour than the internal layer, and this gives rise to certain phenomena which deserve a moment's notice. When, namely, these two layers exist, the septal spines (fig. 3, B) always take their origin from the outer light-coloured layer, and penetrate through the inner laminated and dark layer on their way to the visceral chamber. Hence, in longitudinal sections which divide the *wall* of the corallites (fig. 3, C), we observe vertical rows of small rounded spaces, which have a lighter colour than the surrounding tissues. These light circular spaces might easily be mistaken for pores in the wall, or for transverse sections of canals running in the wall; but they are really the cut ends of the spiniform septa divided near their bases.

5. *Supposed relationships between Tubipora and Syringopora.*—Owing to the marked external resemblance which subsists between the corallum of *Tubipora* and that of *Syringopora*, it has been commonly held by naturalists that the two genera are nearly related, and that the latter genus is, therefore, referable to the *Alcyonaria.* Amongst the later authorities who have adopted this view may be mentioned Zittel ("Handbuch der Palæontologie," vol. i. p. 211) and Moseley ("Voyage of H.M.S. Challenger," vol. ii. p. 125). My own view, on the other hand, has been that there is no real affinity between *Tubipora* and *Syringopora*, and that the latter is really referable to the *Zoantharia perforata*, and allied to the Favositidæ ("Palæozic Tabulate Corals," p. 213). In considering this question with a view to arriving at some decided conclusion, it may be as well to summarise the chief points of likeness and unlikeness between *Tubipora* and *Syringopora.* The points of resemblance between the two genera are as follows:—

(*a.*) It must be admitted, in the first place, that there exists a very remarkable general likeness of the corallum of *Tubipora* to that of *Syringopora.* In both, namely, the corallum consists of slightly separate cylindrical corallites, of comparatively great length, bound together by horizontal processes or floors.

(*b.*) A still more striking point of likeness, as of a really much more fundamental character, is to be found in the fact that in both genera the visceral chambers of the polypes are placed in direct communication by horizontal canals, which run in the interior of the connecting-processes or connecting-floors, to which I have alluded above.

(*c.*) A third point in which it has been alleged that the corallum of *Tubipora* resembles that of *Syringopora*, is the presence in both genera of an axial tube occupying the centre of the visceral chambers of the corallites. Here, however, we have, in my opinion, to deal with a merely apparent similarity and not with a case of true homology. It is true that the axial tube of *Tubipora*, when it is present, is not unlike in appearance to the axial tube of *Syringopora*, but there are important differences between these structures to be noted. Thus, the axial tube of *Tubipora* is an apparently independent calcareous structure, which has no connection with the wall of the visceral chamber save only at the nodal points of the corallite (*i.e.*, at the points opposite to the origin of the horizontal connecting-floors), where it becomes connected with the inner surface of the theca by a funnel-shaped expansion of both its upper and lower extremities. In my view, therefore, there exist *no* "tabulæ" in *Tubipora*. Moreover, the axial tube entirely resembles the wall of the theca in being composed of fused spicules, and it is penetrated by the same close-set canaliculi. What its precise nature may be it is difficult to say, but it is possibly due to a progressive calcification of the wall of the gastric sac from below upwards as the polype grows upwards in the progressively lengthening theca. At any rate, it is interesting to notice that the only points at which it has any connection with the wall of the theca are just those points which, as shown by Professor Perceval Wright, mark the periodic growth from the summit of the polype of the horizontal outgrowths which give rise to the connecting-floors of the colony. On the other hand, the so-called axial tube of *Syringopora* is not in any way an independent and definite structure, with an independent and definite wall. It is, rather, simply the axial space formed by the fitting into one another of a number of irregular funnel-shaped *tabulæ;* and this difference is well shown by a comparison of a transverse section of a corallite of *Tubipora* with a similar section of a corallite of *Syringopora.* In the former case, we see simply two concentric rings, one representing the wall of the theca, while the much smaller inner ring represents the axial tube, the two having absolutely no connection with one another. In the latter case, on the contrary, the section of the corallite shows a number of irregularly concentric lines, marking the cut edges of the ensheathing tabulæ, the outer of these lines being in connection (as a rule) with the wall of the theca, while the innermost encloses the cavity of the axial tube.

While the above are the real or supposed points of resemblance between *Tubipora* and *Syringopora*, there are the following very important differences between the two genera to be observed.

(*a.*) In the first place, there is the very important and remarkable difference in the minute structure of the calcareous skeleton in the two types in question. In *Tubipora* the corallum is made up of fused calcareous spicules, which are so disposed as to give rise to a universally distributed system of minute canaliculi or tubuli, which open on both the outer and inner surfaces of the skeleton by well-marked apertures. The size of these tubuli is comparatively so great that it is quite impossible that their presence could be overlooked in thin sections of *Syringopora*, if they really existed in this genus. On the other hand, the skeleton of *Syringopora*, as regards its minute structure, is quite compact, and shows no signs whatever either of being penetrated by a system of tubuli, or of being formed by the fusion of ectodermal spicules.

(*b.*) True tabulæ are always present in *Syringopora*, and, in all the typical forms of the genus, have the character of a series of invaginated cones, which give rise centrally to an axial tube. In no specimens that I have ever seen, can there be recognised any similar series of funnel-shaped tabulæ in *Tubipora*. I cannot, in fact, recognise that any true tabulæ are present in *Tubipora*, so far as my own observations enable me to come to a conclusion on this point, and, as already stated, I do not regard the axial tube of *Syringopora* as being formed in the same way as the somewhat similar-looking structure in *Tubipora*, or as really being homologous with it.

(*c.*) The corallites of *Syringopora* are provided with a well-developed septal system, of which absolutely no traces can be recognised in *Tubipora*. Moreover, the septa of *Syringopora* are not mere marginal plicæ, such as form the "pseudosepta" of *Heliopora*, but they are in the shape of vertically-arranged rows of spines which may be well compared with the septal spines of such undoubted Zoantharians as *Porites*. A still closer comparison might be made with the septal spines of many species of *Favosites*, but it is unnecessary to do this, as the reference of *Favosites* to the *Zoantharia* would not be universally admitted. Owing to their spiniform character (instead of being lamellar), transverse sections of the corallites can rarely or never show a complete cycle of the septa; and it is, therefore, difficult to determine how many rows of septal spines are present in each coralite. There is, however, no sufficient reason to doubt that the septal spines of *Syringopora* are like those of *Porites* in being really partial calcifications of the mesenteries, so that they are properly of a septal nature.

Taking the whole of the preceding evidence together, I cannot avoid coming to the conclusion that the points of difference between *Tubipora* and *Syringopora* are decidedly more important and fundamental than the points of resemblance. I am not, therefore, at present disposed to alter my previously-expressed opinion that there exists in reality no actual relationship between these two genera, nor am I prepared to admit that *Syringopora* should be rightly referred to the *Alcyonaria*. On the contrary, I think the evidence which is at present available to be decidedly in favour of the view that *Syringopora* belongs to the *Zoantharia perforata*, and that its nearest allies are to be sought for in the Favositidæ, the singular genus *Syringolites* (Hinde), forming a transition between *Favosites* and *Syringopora*. I am aware that Mr Moseley, whose opinion in such a matter deservedly carries exceptional weight, is inclined rather to believe that *Favosites* and its allies should be referred to the *Alcyonaria*. Into this question I cannot enter at this moment; but I hope to be able on a future occasion to show, by means of thin sections of both types, that the affinities of *Favosites* are distinctly with *Porites*, and that the former genus properly belongs, as maintained by Verrill, Zittel, and myself, to the *Zoantharia perforata*.

2. On an Iodine Battery. By Mr A. P. Laurie.

Communicated by Professor Tait.

This is a one fluid battery. The two plates are zinc and carbon. The solution is a solution of iodide of potassium in water, in which iodine is dissolved. The usual strength I use is 1 oz. of iodide of potassium in 2 oz. of water. In this dissolve ½ oz. of iodine, but the strength of the iodine and of the iodide of potassium can be considerably varied without affecting the electromotive force.

The iodine is meant to prevent polarization by uniting with the nascent hydrogen to form hydriodic acid, which will then unite with the caustic potash, to form iodide of potassium and water. In this way the iodide of potassium acts as a carrier of iodine, from the iodine in solution, to the zinc plate.

It is quite possible, however, that the iodine acts directly on the zinc plate.

I made the following experiments:—

On connecting a single cell with a quadrant electrometer, I got a deflection of 60 divisions. The zinc and carbon were then connected by a short wire for ten minutes, and again rapidly connected with the electrometer.

The deflection was now 58. It was joined up for another ten minutes, the deflection was then 57.

The first reading, namely 60, was unusually high, as in no future case did I get more than 58 or 59 to start with.

The following experiment is more trustworthy:—

Initial deflection 58. Current allowed to run for thirty minutes, deflection 57. I tried a whole series of metals, but found none so good as zinc.

The zinc cannot be amalgamated, as the solution acts on mercury. In all these experiments I used commercial zinc. If it is left in the solution it is slowly dissolved, and must therefore be removed from the solution, when the battery is not working.

I made up a Daniell cell with a saturated solution of sulphate of copper, and 1 of commercial sulphuric acid in 12 of water. The Daniell gave a deflection of 54, while my cell gave a deflection of 56. Its electromotive force is therefore about one Volt.

I have lately tried iodide of zinc in place of iodide of potassium. The electromotive force is the same, and in other respects it does as well, iodine being very soluble in it. By using it, the formation of new salts in the cell is avoided.

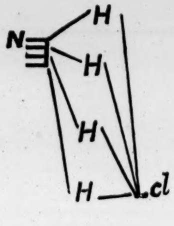
The advantages of this cell are that it gives a fairly constant electromotive force, and can, if the zinc is removed, be left standing unused for any length of time. This is, of course, impossible in the case of the Daniell.

3. Note on Chemical Affinity and Atomicity.

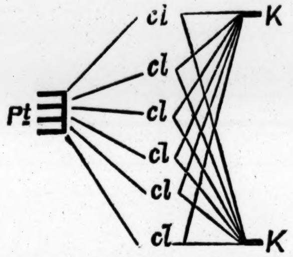
By William Durham.

(*Abstract.*)

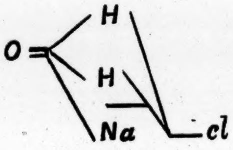
The theory of "Valency" or "Atomicity," while explaining satisfactorily many chemical phenomena, still leaves unexplained many facts, such, for instance, as the varying atomicities of several elements, the composition of double salts, water of crystallisation, &c. This arises from assuming that chemical affinity acts in an atomic indivisible manner, which is not warranted by the facts. If we take, for instance, nitrogen in the compound, NH_3 and NH_4Cl, it acts in the one case as a triad, while in the other it is said to be a pentad. Now, in the case of the NH_4Cl in this view, we have the chlorine represented as directing all its affinity to the nitrogen, for which it usually has such a feeble affinity, while it has no action on the hydrogen, for which its affinity is usually so intense. Now, if we get rid of the idea of the atomic action of affinity, we may represent the chlorine dividing its action among all the four atoms of hydrogen, giving on the average $\frac{1}{4}$ to each; and the nitrogen, in the same manner, giving $\frac{3}{4}$ to each; and thus, the whole molecule is bound together.



Similarly, the double salts, such as the chloride of potassium and platinum, may be represented thus—



The same principle may be applied to water of crystallisation, &c. If this spreading out of chemical affinity be admitted, it may be extended to include solutions and other weak combinations; thus, a solution of salt in water may be represented thus—



and it is manifest any number of molecules of water may be added; each one, of course, weakening the bonds of union. That some such action as this takes place may be inferred from the behaviour of magnesium chloride in water. The chloride cannot be recovered by evaporation, because, from the strong affinity of the magnesium for oxygen, and of chlorine for hydrogen, double decomposition takes place, and hydrochloric acid is liberated, while magnesium oxide remains. The same principle is illustrated by the phenomena of electrolysis, with the varying resistances of solutions of different strength, causing the concentration or diffusion of the chemical affinity.

Alloys, solution, and occlusion of gases may all be included under the law of the spreading of chemical affinity.

There are also some physical facts on which it may throw some light. Thus, the fact that gases in their behaviour under pressure indicate first an attractive, and then a repellant action among their molecules, may be explained by the influences of the component parts of each molecule acting on its neighbours, and producing attraction; while the repellant action may be accounted for by assuming a motion of revolution round an axis when the atoms are at molecular distances, and the pressure would increase angular velocity, and, consequently, centrifugal force at a greater rate than the attractive force.

Andrew's critical point may be explained in the same manner.

4. On the Physical and Biological Conditions of the Channel between Scotland and the Farö Islands. By Sir Wyville Thomson.

BUSINESS.

The following candidates were balloted for, and declared duly elected Fellows of the Society:—Mr A. J. D. Cameron, the Right Hon. the Earl of Rosebery, Mr Walter Berry, Mr John Johnston Rogerson, and Surgeon-Major J. E. Tierney Aitchison, M.D.

Monday, 20th June 1881.

PROFESSOR MACLAGAN, M.D., V.P., in the Chair.

The following Communications were read:—

1. On a Class of Sturmian Functions.
By Professor Chrystal.

2. Preliminary Report on the *Tunicata* of the "Challenger" Expedition. Part IV. By W. A. Herdman, D.Sc.

(*By permission of the Lords Commissioners of the Treasury.*)

IV. MOLGULIDÆ.

The family *Molgulidæ* was established by Lacaze-Duthiers in 1877,[*] and distinguished from the *Cynthiadæ*, with which it had formerly been united by Heller.[†]

Lacaze-Duthiers divides the species known to him into four genera,—*Anurella*, *Molgula*, *Ctenicella*, and *Eugyra*,—of which *Anurella* forms a sub-family or section the *Molgulidæ anuræ*, the other three constituting the *Molgulidæ urodelæ*. The character by which *Anurella* is distinguished from the other genera is the tail-less amœboid larva; but this most interesting developmental difference does not seem to be accompanied by any structural features in the adult animal, and consequently it becomes impossible to distinguish the genus unless one examines the animal alive and at the breeding season.

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[*] Arch. Zool. Expér., vol. vi. p. 457.

[†] Untersuch. ü. d. Tunic. d. Adriat. u. Mittelmeer., Abth. III. p. 1.

I have therefore found it impossible to follow Lacaze-Duthiers in his primary division of the Molgulidæ, and have been compelled in classifying the "Challenger" species to consider *Anurella* and *Molgula* as one genus. Whether *Ctenicella*, separated from *Molgula*, on account of its laciniated lobes round the apertures, will stand as a good genus, I am uncertain. The character is a useful one for working with, and the structure of the apertures seems always an important point in the Tunicata. *Ctenicella* does not occur in the "Challenger" collection. The two remaining genera, *Molgula* and *Eugyra*, seem natural groups, and are both represented in the collection.

In addition to the above, I have had to found a new genus *Ascopera* for the reception of two large species from the Antarctic. Stimpson's *Glandula*, usually considered one of the Molgulidæ, belongs to the sub-family Styelinæ of the Cynthiadæ.

Molgula gigantea, Cunningham.

This large species, first found by Professor R. O. Cunningham in the "Nassau" expedition, and described by him as *Cynthia gigantea*, was taken in considerable numbers by the "Challenger" in the Strait of Magellan.

Station 313; 55 fathoms.

Molgula gregaria, Lesson.

The *Cynthia gregaria* of the "Centurie Zoologique" seems identical with specimens dredged by the "Challenger" at Station 315 (Falkland Islands), 5 to 10 fathoms. The species was also obtained at this locality by Professor Cunningham in the "Nassau."

Molgula pedunculata, n. sp.

External appearance.—Shape ovate or pyriform, elongated transversely, the ventral edge forming a short thick stalk, the rest of the body globular, slightly compressed laterally; dorsal edge and posterior end convex, attached by extremity of ventral edge. Apertures both on wide anterior end, sessile, not conspicuous; atrial, regularly lobed. Surface smooth. Colour white, with a hyaline tinge Length, 4 cm.; breadth, 5 cm.

Test cartilaginous, thickish, strong; smooth and glistening on inner surface.

Mantle not very thick; muscle bands distinct, but distant.

Branchial sac with seven folds on each side. Internal longitudinal bars strong, placed between as well as on the folds. Transverse vessels variable. Stigmata arranged in irregular transverse rows, rarely in spirals.

Dorsal lamina short, but very wide; plain.

Tentacles large, branched, about twelve in number, placed larger and smaller alternately. One very large one occurs at the ventral edge, just anterior to the extremity of the endostyle.

Olfactory tubercle a long way posterior to the tentacular circlet, equidistant from the branchial and atrial siphons; horns simply turned in, opening directed dorsally and to the left.

One specimen from Station 150 (south of Kerguelen Island); 150 fathoms.

Molgula horrida, n. sp.

External appearance.—Shape rudely ovate; posterior end rounded, wide; anterior end narrower; ventral edge very convex, dorsal concavo-convex going from the anterior to the posterior end. Attached by the ventral part of the left side. Apertures both at the anterior end, not distant, slightly projecting, lobes irregular. Surface rough, almost entirely covered with sand, and other animals adhering. Colour—Where visible, the test is dull brown. Length, 5 cm.; breadth, 5 cm.

Test thick and solid, very stiff; smooth and glistening on the inner surface.

Mantle very thick, but not very muscular; siphons wide, tubular.

Branchial sac of a dark green colour, very thick; seven folds on each side. Internal longitudinal bars prominent, connected by horizontal membranes; transverse vessels irregular; meshes square, and cut up by an irregular network, formed by vessels arising from the transverse and internal longitudinal bars. In this network lie the delicate, coiled interstigmatic vessels.

Dorsal lamina short, quite plain; no ribs nor teeth.

Tentacles large and branched, dark green, ten in number, with a few additional very small intermediate ones.

Olfactory tubercle prominent, both horns much coiled, forming large spirals.

Two specimens from Station 315 (Falkland Islands); 5 to 12 fathoms.

Molgula forbesi, n. sp.

External appearance.—Shape globular, slightly elongated dorso-ventrally, not compressed laterally; posterior end regularly rounded; edges convex; anterior end slightly projecting and flattened, not attached. Apertures both at anterior end, not distant; atrial rather more prominent than branchial, both slightly projecting, branchial pointing ventrally. Surface entirely covered with a close coating of sand grains. Colour dull brown. Length, 1·8 cm.; breadth, 2 cm.

Test not thick, but stiff; quite opaque.

Mantle thin, transparent, viscera seen through distinctly; muscle bands numerous, but very fine.

Branchial sac with seven folds on each side. Internal longitudinal bars strong, three or four on each fold. Stigmata very irregular—being straight, and arranged in transverse rows in some places, while in others they are curved and arranged in spirals or irregularly. Transverse vessels varying greatly in size and position, often quite irregular. Delicate horizontal membranes frequently present between the folds.

Dorsal lamina, a short and narrow membrane, with a plain edge.

Tentacles compound, about twelve large and twelve small placed alternately.

Olfactory tubercle simple, placed at the posterior end of a deep and irregular peritubercular area. The left side extending further forwards than the right; both horns turned to the left.

One specimen from Port Jackson, Australia; 2 to 10 fathoms

Molgula pyriformis, n. sp.

External appearance.—Shape pyriform, almost triangular; anterior end wide, truncated; posterior narrow, pointed; both edges convex.

The widest part is one-third of the way down, and from there both dorsal and ventral edges taper rapidly to the posterior end; not attached. Apertures at the extremities of the flat anterior end, not projecting, inconspicuous; branchial rather the more anterior of the two. Surface entirely covered with a close coating of sand grains. Colour dark brown. Length, 2 cm.; breadth, 1·5 cm.

Test thin, but stiff.

Mantle thin. Musculature moderately developed.

Branchial sac, with seven folds on the right side and six on the left. These folds have no stigmata, but consist merely of an open network formed by internal longitudinal bars and transverse vessels, which are frequently joined across the intervening stigmatic region by horizonal membranes. Fine interstigmatic vessels, arranged in rather distant and irregular rows of spirals. Stigmata curved in the spirals, and more or less linear between.

Dorsal lamina narrow and plain.

Tentacles branched, of many sizes.

Olfactory tubercle tubular, having a wide funnel-shaped aperture anteriorly; no horns.

One specimen from Station 320 (off the coast of Buenos Ayres), 600 fathoms.

Eugyra kerguelenensis, n. sp.

External appearance.—Shape globular; very slightly elongated dorso-ventrally; not compressed laterally; posterior end rounded, not attached. Apertures both anterior, conspicuous, not distant; branchial sessile; atrial prominent, forming a short cylindrical projection. Surface smooth; slightly wrinkled round the apertures. Colour light transparent grey. Length, including atrial siphon, 2 cm.; breadth, 1·8 cm.

Test very thin and transparent, except on the atrial siphon.

Mantle thin. Muscular fibres few, radiating from the apertures.

Branchial sac strong; not folded. Internal longitudinal bars broad and thin bands. Transverse vessels slight and irregular; narrow horizontal membranes usually present. Spirals large and much coiled, having from ten to thirty turns (generally fifteen to twenty). Radiating vessels slight; a few short intermediate ones frequently present.

Dorsal lamina, a plain broad membrane.

Tentacles branched, thin, about twelve large and twelve smaller, and three orders of simple and very minute ones placed alternately to the others.

Olfactory tubercle having an elongated oval cavity, ending in a quadrangular aperture anteriorly. No horns.

Four specimens from Kerguelen Island; 10 to 110 fathoms.

Ascopera, n. gen.

Body pyriform, more or less pedunculated; attached.

Test thin, between membranous and leathery.

Branchial sac, with seven folds on each side. Stigmata straight or curved, but not arranged in spirals.

Ascopera gigantea, n. sp.

External appearance.—Shape roughly pyriform, not compressed laterally. Anterior end wide, truncated, slightly cleft in the centre, ending in a siphon at each extremity. Behind the siphons the body swells out into a globular form, and then becomes continuous with the wide stalk formed by the posterior two-fifths of the test. Dorsal edge rather more convex than ventral. Attached by the extremity of the posterior end. Apertures both at anterior end, distant, conspicuous, wide; branchial at the ventral edge, very large, funnel-shaped; bent round so that the opening is directed posteriorly; atrial at the dorsal edge, more anterior than branchial, wide, directed anteriorly. Surface even; finely roughened all over. Colour pale yellowish grey-green. Length, 30 cm.; breadth, 12 cm.

Test thin and almost membranous, but tough; semi-transparent; smooth on inner surface.

Mantle delicate and membranous, with a few distant, rather strong muscle bands running transversely over the anterior half or so of the right side and the left side; only absent on the dorsal part of the left side and the posterior end.

Branchial sac very thin and delicate, seven folds on each side; those next the endostyle are rather slighter than the others. Internal longitudinal bars wide and delicate. These and the wide and distant transverse bars give off vessels which branch and anastomose, forming an irregular network, the spaces of which are the stigmata.

Dorsal lamina short, 4 mm. wide, and rather thick. No ribs nor teeth.

Tentacles branched; eight large and eight small placed alternately, and about sixteen very minute ones placed between the others; the largest are of considerable size, and are strong.

Olfactory tubercle large, prominent. Both horns much coiled.

One specimen from Station 150 (south of Kerguelen Island); 150 fathoms.

Ascopera pedunculata, n. sp.

External appearance. — Club-shaped, consisting of a rudely diamond-shaped body on a thick stalk, somewhat compressed laterally. Anterior end straight, wide, truncated; dorsal and ventral edges nearly straight, sloping outwards and backwards to the wide posterior end; posterior end prolonged into the long stalk which springs from its ventral edge, and is twice as long as the body. The stalk is thin, being compressed laterally. It is narrow where it joins the body, and increases gradually in width as it proceeds backwards, till, at the posterior end, where it is attached, it is more than twice its original width. Apertures at the extremities of the anterior end, distant, conspicuous, slightly projecting, distinctly lobed; branchial at ventral edge, directed ventrally; dorsal at dorsal edge, directed dorsally. Surface even, slightly roughened all over. Stalk smooth. Colour pale grey. Length of body, 7·5 cm.; breadth of body, 7 cm.; length of stalk, 17 cm.; breadth of stalk, 4·6 cm.

Test moderately thick and tough on body; very thin and membranous on stalk.

Mantle thin and membranous, or semi-gelatinous. The posterior part is prolonged for 13 cm. into the peduncle.

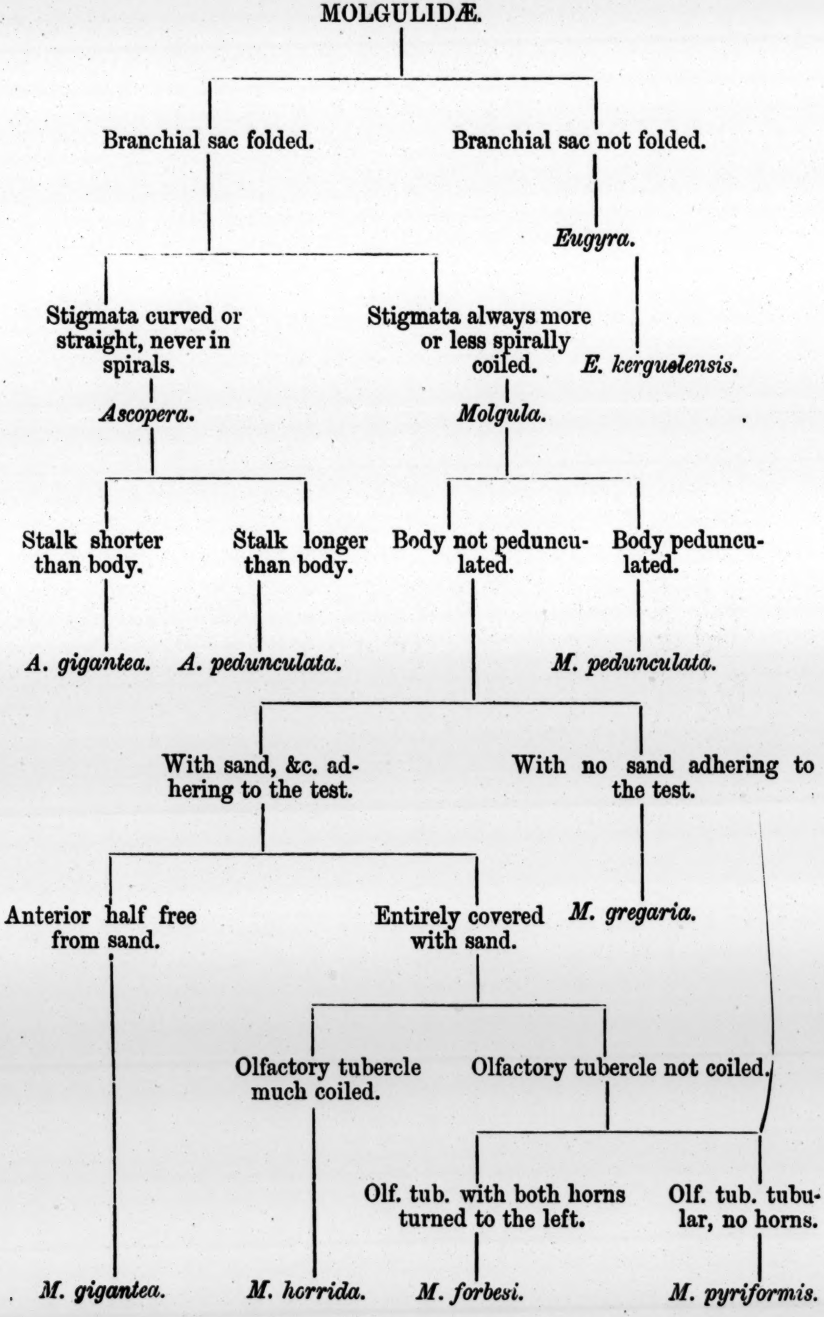
Branchial sac with seven folds on each side. Internal longitudinal bars delicate, not distant. Transverse vessels rather irregular; generally several more or less perfect smaller vessels between the larger ones. Meshes greatly elongated transversely. Stigmata of different lengths, but all running longitudinally.

Dorsal lamina broad but thin and short.

Tentacles large, branched, sixteen in number; placed long and short alternately.

Olfactory tubercle prominent, elongated transversely, having the aperture placed laterally. Horns large, both coiled outwards.

One specimen from Station 150 (south of Kerguelen Island); 150 fathoms.


MOLGULIDÆ.
Branchial sac folded.
Branchial sac not folded.
Eugyra.
Stigmata curved or straight, never in spirals.
Stigmata always more or less spirally coiled.
E. kerguelensis.
Ascopera.
Molgula.
Stalk shorter than body.
Stalk longer than body.
Body not pedunculated.
Body pedunculated.
A. gigantea.
A. pedunculata.
M. pedunculata.
With sand, &c. adhering to the test.
With no sand adhering to the test.
Anterior half free from sand.
Entirely covered with sand.
M. gregaria.
Olfactory tubercle much coiled.
Olfactory tubercle not coiled.
Olf. tub. with both horns turned to the left.
Olf. tub. tubular, no horns.
M. gigantea.
M. horrida.
M. forbesi.
M. pyriformis.

3. Comenic Acid. By D. B. Dott. Communicated by Professor Crum Brown.

In continuation of a short paper on meconic acid previously communicated to the Society, I submit the following notice of some of the salts of comenic acid.

As is well known, comenic acid is formed from meconic acid by elimination of carbonic anhydride, according to the equation - $C_7H_4O_7 = C_6H_4O_5 + CO_2$. This change may be effected by heat alone, but a better product is obtained by the action of boiling aqueous hydrochloric acid. It was by the latter method that the acid used in my experiments was prepared. Comenic acid is easily purified by crystallisation from boiling water, in which it is sparingly soluble, and by conversion into ammonium salt, which is likewise purified by recrystallisation. Comenate of ammonia forms long well-defined prisms, which are much less soluble in water than the corresponding salt of meconic acid.

I have endeavoured to prepare most of the salts of comenic acid as described by How* and others, with results generally in accordance with their experiments. I have also succeeded in obtaining two crystalline comenates of silver, or rather the same salt crystallised in two different forms. The silver salts hitherto noticed were amorphous.

Silver Salt.

(1.) This was prepared by adding nitrate of silver to solution of ammonium comenate, the precipitate being dried in water-bath. 8·205 grs. gave by ignition 3·190 grs. Ag = 38·87 per cent.

(2.) Prepared by adding excess of nitrate of silver to solution of ammonium comenate. The air-dry precipitate dried in air-bath at 120° C.

10·78 grs. gave by ignition 4·44 grs. Ag = 41·18 per cent.
5·04 grs. „ 2·08 grs. Ag = 41·26 „

(3.) Nitrate of silver was mixed with solution of ammonic comenate rendered alkaline by ammonia, the precipitate being dried at 120° C.

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* Ed. Phil. Trans., xx. 225.

8·01 grs. gave by ignition 4·60 grs. Ag = 57·42 per cent.

Of another quantity, prepared in the same way, 8·86 grs. give 5·02 grs. Ag = 76·65 per cent.

(4.) Aqueous solutions of argentic nitrate and ammonic comenate were mixed, the precipitate produced being washed by decantation. The beaker containing the same was then covered and placed in the dark. After a few days crystals had appeared, and these gradually increased in number until the whole of the original amorphous precipitate had disappeared. These crystals were removed from the beaker and dried on blotting paper and by exposure to the air. They have the form of hexagonal prisms, and are of a brown colour. The weight was not altered by exposure to a temperature of 100° C.

14·21 grs. gave by ignition 5·43 Ag = 38·21 per cent.

(5.) The amorphous precipitate above mentioned was boiled with water for several hours, and then filtered. On cooling the filtrate deposited small white crystals, which under the microscope presented the appearance of flat four-sided prisms. These crystals after drying in the air at the ordinary temperature lost no weight at 120° C.

6·07 grs. gave 2·32 grs. Ag = 38·22 per cent.

Another portion, exposed to temperature of 160° C. until it had almost ceased to lose weight, became darker in colour as if slightly decomposed.

10·15 grs. gave 4·175 grs. Ag = 41·13 per cent.

(6.) A quantity of the amorphous silver comenate was boiled with water for thirty hours, the residue collected on filter, washed with hot water, and dried in water-bath.

8·03 grs. gave 7·95 grs. Ag = 99·00 per cent.

$C_6H_3AgO_5H_2O$ = 38·43 Ag per cent.
$C_6H_3AgO_5$ = 41·06 Ag ,,
$C_6H_2Ag_2O_5H_2O$ = 55.67 Ag ,,
$C_6H_2Ag_2O_5$ = 58·37 Ag ,,

From these results it is manifest that the amorphous precipitate produced in solution of ammonic comenate, as likewise the crystalline salt above described, are the monobasic silver salt. The only product that approximates in composition to di-argentic comenate is the precipitate produced in the *alkaline* solution of comenate of ammonia. From experiment (6) it is evident that when argentic comenate is boiled with water, the silver is reduced to the metallic state; reduction taking place much more readily than with the corresponding meconate.

Copper Salt.

This was prepared by adding excess of cupric sulphate to a hot solution of ammonic comenate. A crystalline precipitate separated immediately, increasing in quantity as the solution cooled. The crystals dried at 120° were ignited, the residue dissolved in hot nitric acid, and caustic soda solution added to the boiling nitrate of copper. The precipitated oxide was washed by boiling with water, then on the filter with hot water, and finally ignited. 8·615 grs. gave 2·910 grs. $CuO = 33{\cdot}77$ per cent. $C_6H_2CuO_5H_2O$, is $= 33{\cdot}73$ CuO per cent.

Calcium Salts.

(1.) Prepared by adding solution of calcic chloride to warm solution of ammonic comenate. The salt so obtained was recrystallised from boiling water, and after drying in the air, exposed to heat of air-bath at 120°.

9·870 grs. lost 2·515 grs. = 25·48 per cent.

The dried substance was ignited, converted into sulphate, and again ignited. It gave 2·81 grs. $CaSO_4 = 0{\cdot}826$ grs. $Ca = 8{\cdot}36$ per cent.

$(C_6H_3O_5)_2Ca7H_2O$ would yield 26·47 H_2O, and 8·40 Ca per cent.

(2.) A strong solution of ammonium comenate was rendered alkaline by addition of ammonia, and poured into saturated solution of calcic chloride. An indistinctly crystalline precipitate separated. When dried at 120° C.

11·26 grs. gave 7·24 grs. $CaSO_4 = 2{\cdot}98$ CaO = 26·45 per cent.
12·28 grs. gave 7·40 grs. $CaSO_4 = 3{\cdot}047$ CaO = 26·42 „

(3.) By adding alkaline solution of ammonic comenate to dilate solution of calcic chloride, a precipitate was obtained which separated for the most part gradually.

3·64 grs. gave 0·99 grs. $CaO = 27·19$ per cent. in the salt dried at 120°.

$C_6H_2CaO_5 = 28·86$ per cent. CaO.
$C_6H_2CaO_5H_2O = 26·41$ „

None of the other salts described in the books was prepared, as the analyses given of them did not afford promise of any good result. It occurred to me that it would be interesting to observe the behaviour of comenic acid when digested with a strong alkaloid, and the experiments though inconclusive are worth noting. With morphine, which is not a very powerful base, only the mono-morphine comenate is formed, just as with meconic acid it forms the di-morphine meconate. Codeine, which is a very strong alkaloid, when digested in water with comenic acid in the proportions to form di-codeine comenate, readily dissolves, and when the solution is evaporated it remains for days in a syrupy state without any separation of codeine. As however the salt refuses to crystallise, there is no proof that the di-basic salt is really formed. The result may simply be due to the solubility of codeine being greatly increased by the presence of the mono-basic comenate. At the same time it must be observed, that when codeine (in excess of the quantity required to form the di-basic salt) is digested with comenic acid, very little more of the alkaloid is taken up than is required to form the di-codeine comenate, and this excess is easily explained by the solubility of codeine in water. In like manner, meconic acid takes up very nearly the proportion of base required for the tri-codeine meconate. The only other alkaloid tried was thebaine, and it behaved exactly as morphia.

In view of the results above described, I think we must admit that the evidence is distinctly in favour of the di-basic nature of comenic acid, and apparently of the tri-basic nature of meconic acid, although the last combining power in each of them must be very feeble. Knowing that carbonic anhydride is evolved in the formation of comenic from meconic acid, it is naturally assumed that the former contains an oxatyl radicle less than the latter; but as we do not know the constitution of either of them, we are not compelled to accept this conclusion. It must, however, be allowed that if comenic acid is shown to be di-basic, there is strong presumption that meconic acid is tri-basic. One of the circumstances which at first led me to form an opinion different from that which I now hold, is the fact that, in a solution supersaturated with ammonia, the acid comenate of ammonium crystallises out; but I suppose this must be explained by the law, according to which the most insoluble compound always tends to form. There are several experiments which suggest themselves in connection with this subject, such as the use of different solvents, evaporation *in vacuo*, and the like, but in the meantime I cannot further follow the investigation.

4. On Morgan's Systems of Consanguinity and Affinity.
By Dr Macfarlane.

5. Note on a Proposition in Theory of Numbers.
By Professor Tait.

Monday, 4th July 1881.

Mr D. MILNE HOME, Vice-President, in the Chair.

At the request of the Council, an Address on the Island of Socotra was given by Professor I. Bayley Balfour.

The following Communication was read:—

2. On some new species of Fossil Scorpions from the Carboniferous Rocks of Scotland and the English Borders, with a Review of the genera *Eoscorpius* and *Mazonia* of Messrs Meek and Worthen. By B. N. Peach.

Monday, 18*th July* 1881.

SIR ALEXANDER GRANT, Bart., Vice-President,
in the Chair.

The following Communications were read:—

1. Report of the Boulder Committee, with Remarks by the Convener, Mr D. Milne Home. (Plates I., II., III.)

NOTES BY CONVENER.

ARGYLESHIRE—CRINAN CANAL.

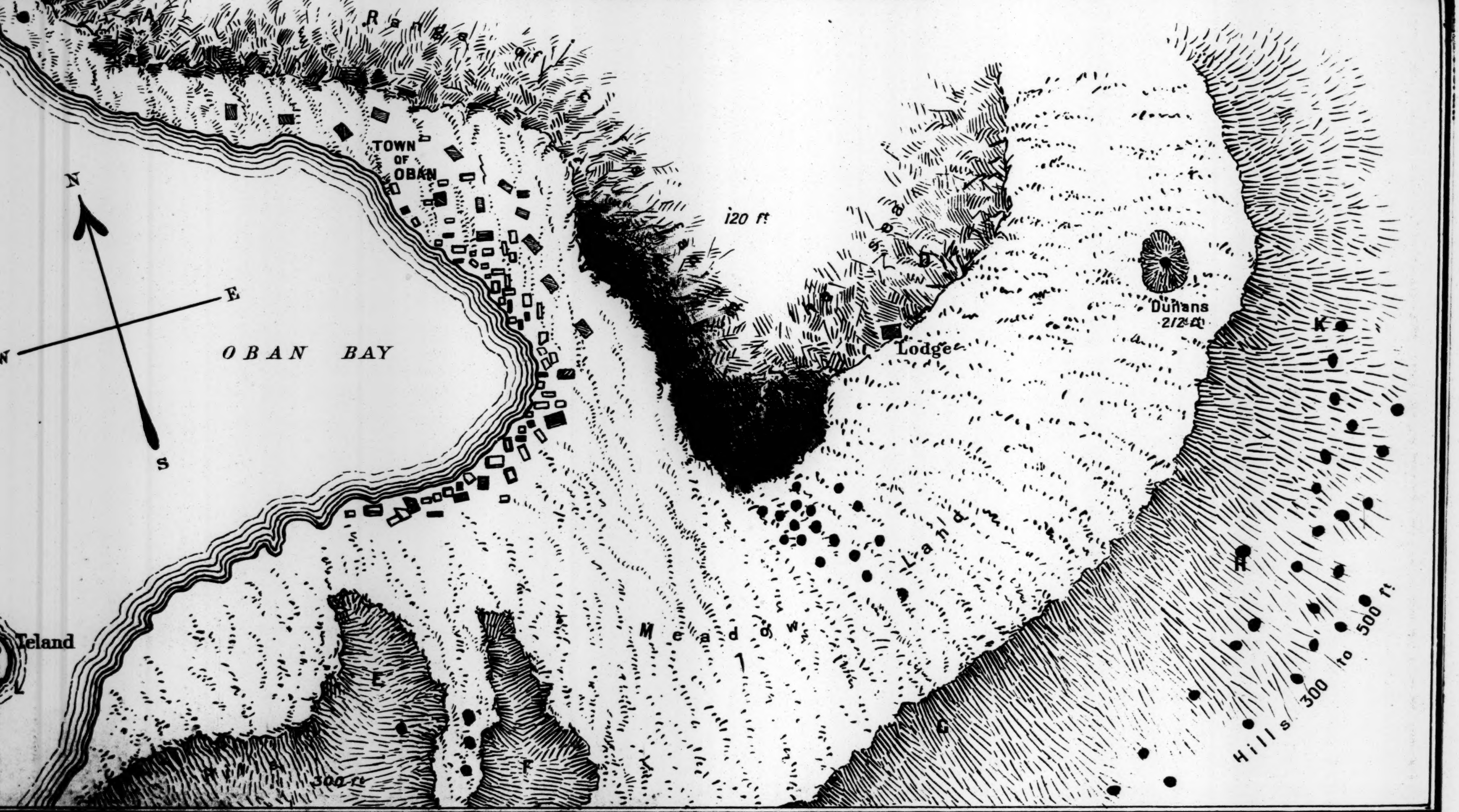
1. Between Crinan Bay on the north and the head of Loch Fyne on the south, there is a trough or hollow now occupied by the Crinan Canal. The highest point along this trough, is about 150 feet above the sea. A series of locks occur at this summit-level, to allow of the passage of vessels between the two sea-lochs.

At the summit-level, the rocks form a sort of ridge across the valley, with smooth surfaces towards the north, and rough surfaces towards the south.

On both sides of this rocky ridge, there are large boulders; on the north side, I counted between forty and fifty, on the south side, there are not more than two or three. The boulders are a syenitic gneiss; the rocks *in situ*, are shivery clay slate, nearly vertical, dipping steeply towards the south.

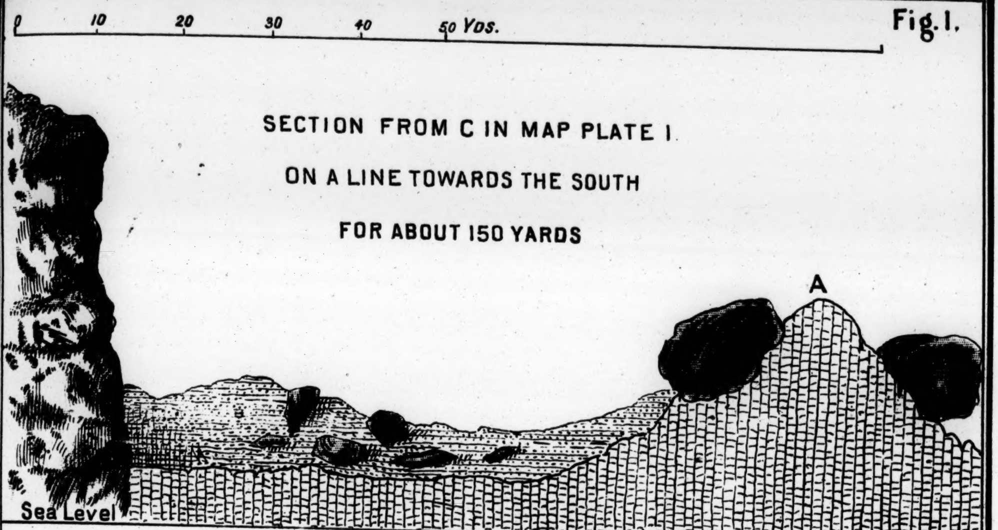
Three or four of the boulders on the north side, I found pressed or squeezed up against the rocks *in situ*, in such a way as to show that they had come from the north, and had been obstructed in their farther progress southwards by the rocky ridge. In one case, the boulder lies with its longer axis N.N.W., which is about the direction of the valley at this place. There is a hollow on the north side of the ridge, as if made by the force with which the boulder had been pushed or driven against it. Other two boulders were in size 10 × 5 × 4 feet, with the longer axis W.N.W., and 9 × 5 × 4 feet, with longer axis and sharpest end due north.

DISTRICT EAST AND SOUTH OF OBAN



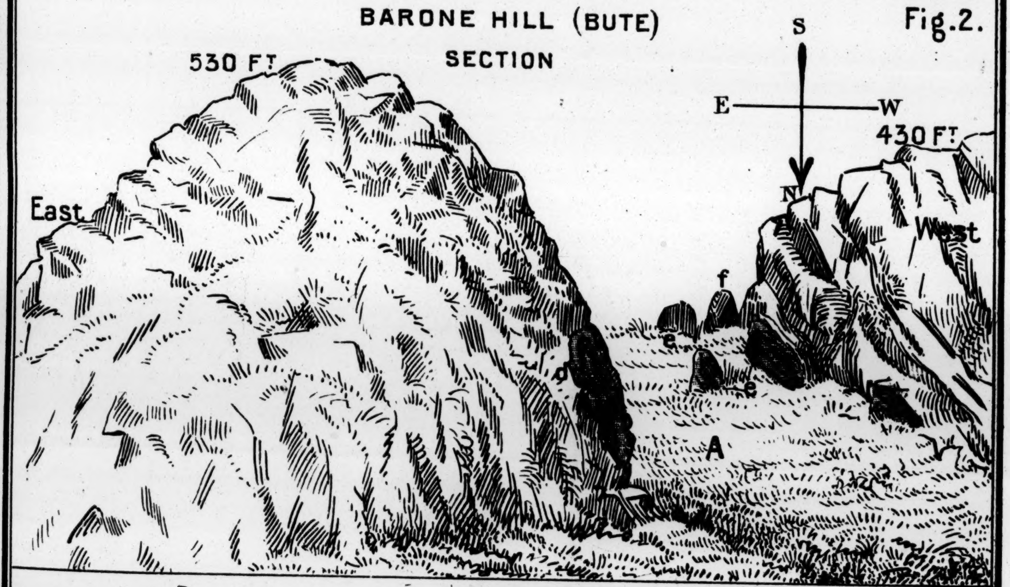
Conglomerate Boulders in brown colour:—Granite D^o in green colour.

Fig. 1.



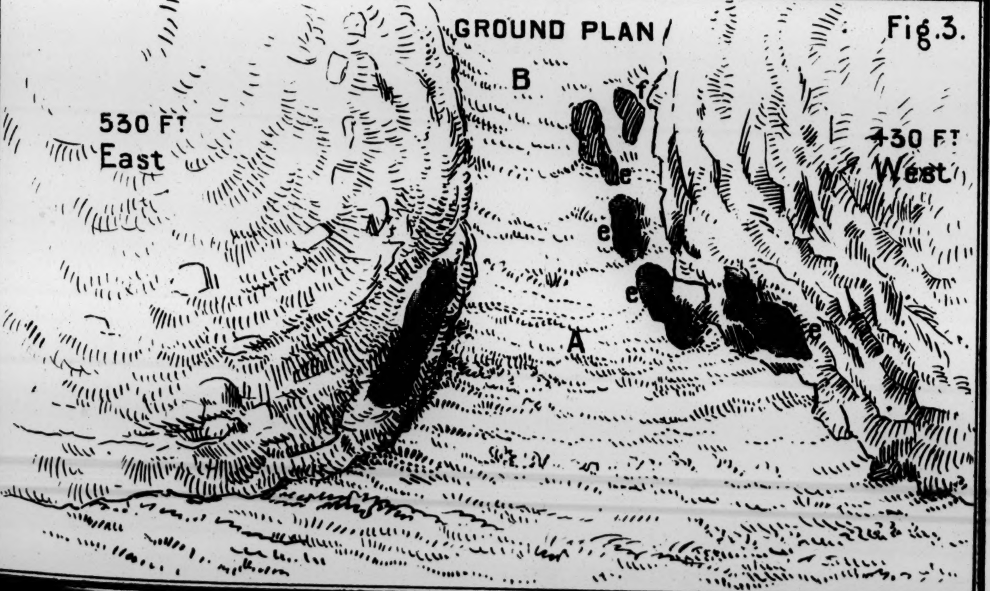
SECTION FROM C IN MAP PLATE I ON A LINE TOWARDS THE SOUTH FOR ABOUT 150 YARDS

Fig. 2.



BARONE HILL (BUTE) SECTION

Fig. 3.



GROUND PLAN

Fig. 1.

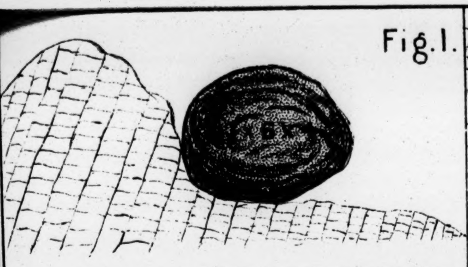


Fig. 2.

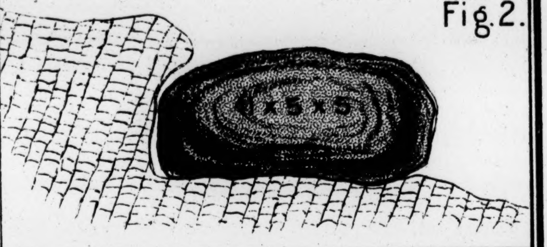


Fig. 3.

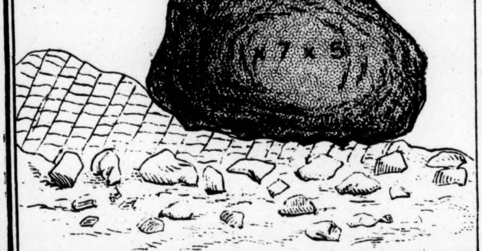


Fig. 4.

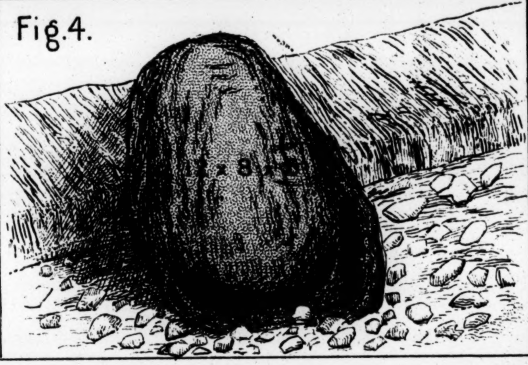


Fig. 5.

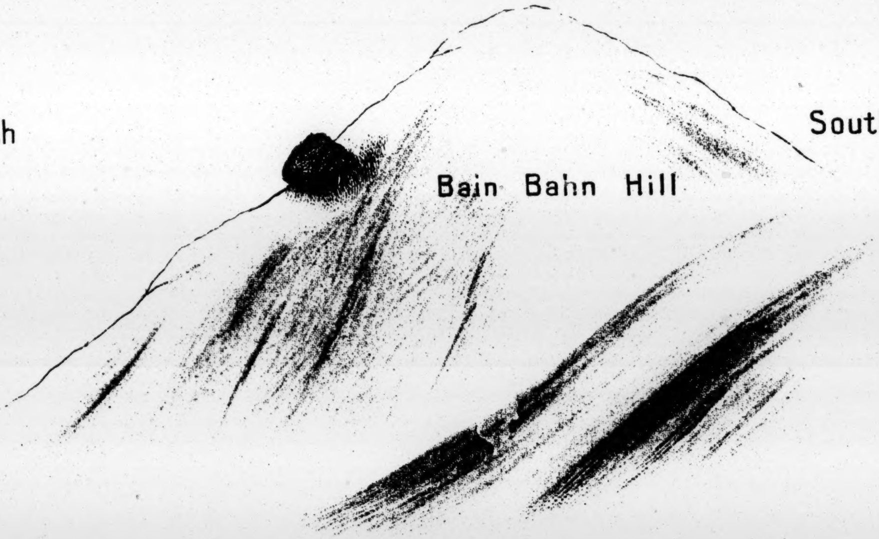
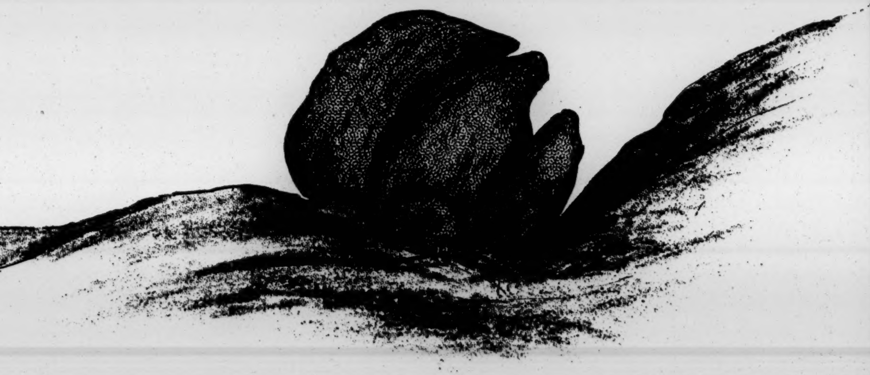


Fig. 6.



Many others were blocked in a similar manner. Plate III., figs. 1 and 2, represent two of these boulders.

The boulders on the south side of the ridge, are of much the same size, but are not close to the ridge; they may have tumbled over the ridge by falling from the agent which brought them when it stranded on the ridge. The spot now referred to adjoins the small stream which flows down from the tanks for supplying the Crinan Canal. These tanks a number of years ago burst, and many large fragments of rock came down with the torrent, but these are quite distinguishable from the boulders above mentioned.

In reference to the agent which may have brought these boulders from the north, there is nothing to suggest the action of a glacier, as the trough forming the bed of the Crinan Canal, towards the north, unites with an arm of the sea at the distance of only about 2 miles. That, at some former period of the earth's history, this Crinan Canal trough was occupied by the sea, through which floating ice might flow, is evident from the well-known traces of old sea-margins visible on the adjoining coasts up to at least 300 feet above the present sea-level. At the summit-level in this Crinan Canal trough, the width of the valley is narrower than anywhere else—probably not more than 300 yards, so that floating ice passing through this Kyle would easily choke there.

Mr Jamieson, in one of his papers published in the London Geological Society's Journal, alludes to this trough, now the bed of the Crinan Canal, and states that he found smoothed rocks on the east side of the valley, and striations running N.W. and S.E. I did not see these markings. They are not inconsistent with the theory above suggested as to the transport of the boulders.

2. *Oban.*—At the south end of the town there is a large number of huge blocks of the Old Conglomerate rock, which forms high and steep cliffs both east and south of the town.

On Plate I. there is a sketch of the district occupied by the town and by a portion of the hills to the east and south, copied from the Ordnance Survey Map. The cliffs on the east side of the town (A B C) have nearly vertical fronts, facing the sea. They reach to a height of from 120 to 150 feet above the sea-level. At C these cliffs take a sudden turn to the eastward. The rocks at B C are a coarse red conglomerate, which face about due west. At E F there are hills reaching to a height of 300 feet above the sea. Between the cliffs B C and the hills E F, the distance is about one-third of a mile, and the ground between is so flat, that the sea at spring tides flows on to it. There is a meadow up to Dunans, the surface of which nowhere exceeds 20 feet above the sea. At Dunans, however, there is a knoll of conglomerate rock, the top of which reaches to a height of 212 feet above the sea.

The green-coloured dots indicate spots where boulders occur. It will be perceived that they abound on the hill-slopes at H and K facing the N. and N.W. They are almost all grey granite, pretty well rounded, and having a diameter from 5 to 7 feet. One boulder, out of about twenty which I examined, was of porphyry, with white felspar crystals in a basis of purple alumina.

In the meadow or valley to the north of the hills G H K many boulders of grey granite are lying about. The largest I found was on Dunans Knoll, and on the side of the knoll facing N.W.

To the south of the conglomerate cliffs at C, there is a *trainée* of conglomerate boulders (coloured brown), evidently derived from these cliffs. They form a line running about S.E.; most of them are about 80 or 100 yards from the cliff, and one or two occur in the low ground about 200 yards from the cliff.

Some of these boulders are buried in a mass of gravel (as shown in Plate II., fig. 1) 10 or 12 feet thick, lying on the edges of the vertical strata of dark-coloured clay slate. The pebbles in the gravel are chiefly grey granite and gneiss. There is a quarry at this place which shows well, a section of the gravel. In another part of the quarry, there is a bed of laminated clay, 4 feet thick, lying between the rocks and the gravel. The workmen in the quarry informed me, that they had seen sea shells in this clay bed, but I was unable to reach the bed to search for shells, on account of its inconvenient position.

One of the conglomerate boulders lies against a rocky knoll A, which has apparently obstructed the progress of the boulder farther south. Several others lie to the S.E., in the meadow, as if tumbled off the agent, whatever it was, which carried them.

The new railway from Oban to Dalmally cuts through a portion of the hill composed of dark blue slate rocks (see F, Plate I.).

Over these rocks lies a bed of boulder clay containing granite boulders. One which I found undisturbed, measured 5 × 3 × 3 feet, with its longer axis pointing N. by E. and S. by W.

On walking over the hills E F (Plate I.), situated above Professor Blackie's cottage, I fell in with a valley about three-quarters of a mile long, opening towards the north. The bottom of the valley is about 80 feet above the sea, with hills on each side reaching to about 300 feet, and blocked at its south end by a range of hills about 600 feet above the sea. In this valley, I found two or three granite boulders, from 3 to 4 feet in diameter, on the east side of the valley, at a height of about 120 feet above the sea, lying on slate rocks. These granite boulders could not have come into this valley except from the north. The width of the valley is from 300 to 400 yards. From the peculiar position of the boulders on the east side of the valley, it may be very probably inferred, that they had come from some north-westerly point.

The sides of the valley where these boulders lie, are at present exceedingly steep, and it seemed marvellous that if they fell on the surface where they now lie, they did not roll to the bottom. It occurred to me that probably when these boulders arrived, the valley was filled with gravel, and that as the gravel was scoured out by streams, the boulders slowly subsided to their present positions.

On the west side of the valley, there is another grey granite boulder, at a level about 30 feet higher than the site of those just mentioned. It is 4 × 3 × 3 feet, and with its longer axis pointing N.N.E.

At the north end of Oban Bay, the grey granite boulder is situated, which was mentioned in last year's Report (p. 11). Its position is indicated on Plate I. by the green-coloured dot near the letter A. Its position close to the high conglomerate cliff raises a presumption that it had come from the westward, and had been intercepted in its farther progress by the cliff. This is strengthened by the fact mentioned in last year's Report, that its longer diameter points W. by N. It probably came by the same agency, whatever that was, which brought the other grey granite boulders shown in Plate I.

I examined the small island in Oban Bay opposite to Professor Blackie's cottage, near the east side of Kerrera Island (L in Plate I.).

Professor Duns having landed on this island in a previous year, had noticed several boulders, and suggested that I should visit it. I found on it four or five grey granite boulders, the rock of the island being entirely conglomerate. One or two of the boulders were in positions indicating probable transport from the north.

I proceeded next round the north end of *Kerrara Island* as far as Bal-na-bok Bay; landing, on my way there, at parts of the shore where boulders were observable. At the north end of Kerrara, where the rocky cliffs of conglomerate reach a height of about 100 feet, I found four or five large boulders of granite, all grey but one, which was red. Their position close to these high cliffs suggested that they had come from some northern point, and had been intercepted there.

On a small island near the same place, there is a grey granite boulder, 8 × 5 × 4 feet, and in such a position as also to indicate transport from the north.

On reaching Bal-na-Bok, I found the shepherd and his daughter (M'Kinnon) very willing to guide me across the hills, and point out a number of boulders known to them. Accordingly, in the course of a three hours' circuit among hills about 300 feet above the sea, I examined about twenty boulders, all granites except one, which was a greenstone. Some of the granites had a pinkish tinge of colour. Most of the boulders were lying with their longer axis N. and S., but there was nothing in their positions to show from which quarter they had come.

The late Robert Chambers (Edin. New Philosoph. Journal for 1853, p. 254), mentions having seen in Kerrera Island "numerous smoothed (rock) surfaces dipping into the sea, with striations from N. 60° W., being nearly the same direction as Mr Maclaren's W.N.W." I did not fall in with any of these. He mentions "that on the high grounds above Tobermory, in Mull, there are striæ pointing from N. 60° W."

3. Having been informed of a large boulder on the hills on the south side of the road between Oban and Connal Ferry, on the farm of *Dunbeg*, I called on Mr Brown the tenant, and induced him to guide me to the place. The hill-slopes here face the north, and the boulder was on one side of a niche in this range of hills. The Linnhe Loch is on the north side of the range.

Its position between the hills is indicated by × on the annexed diagram (fig. 1), which shows the ground plan of a narrow valley, open at each end, about 500 yards in length, about 50 yards wide, and with sides from 200 to 300 feet high. Fig. 2 shows a section across this valley, with the boulder on the west side, upon a shelf, at the height of about 250 feet above the sea. The boulder measures 11 × 6 × 5 feet, and the longer axis points N.N.W. and S.S.E.

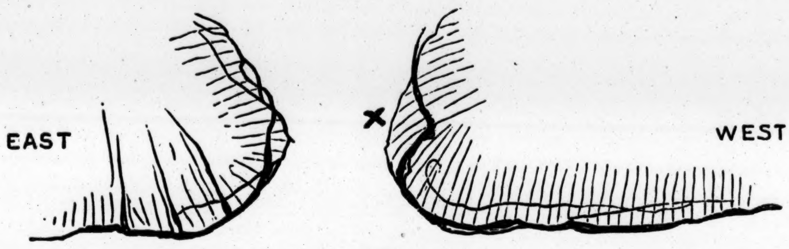


Fig. 1.

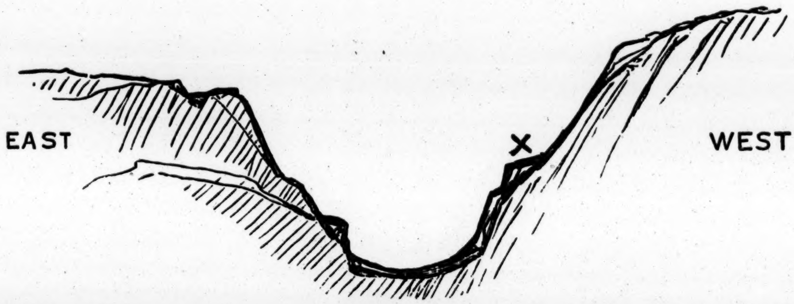


Fig. 2.

The axis of the valley, which rises to the south, is N.W. and S.E.

The rocks here are clay slate, the boulder is grey granite.

In reference to the transporting agent, it is almost certain that the boulder must have been brought into the valley, by either its north or its south end.

From the boulder, Ben Cruachan is visible, bearing E.S.E. at a distance of about 10 miles. If a glacier be thought of to bring it from Cruachan, there are hills and valleys in the way, rendering the course of a glacier along that line most improbable. The more natural course of a glacier would be down Loch Etive. On the other hand, there seems to be nothing improbable in the supposition, that it may have been brought by floating ice from the north.

In making a short tour across the adjoining hills, I found many other boulders of grey granite, and mostly on hill slopes facing the north. One of these boulders, 6 × 4 × 4 feet, lay on a sort of shelf blocked at its S.E. end.

4. At *Dunstaffnage*, about 5 miles N.E. of Oban, there is a conglomerate rock on which the old castle stands, as shown on fig. 3.

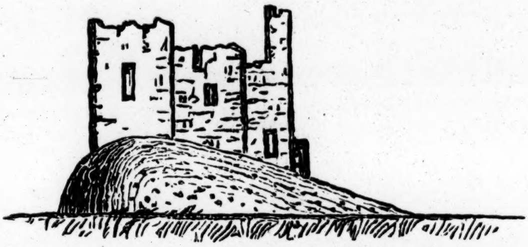


Fig. 3.

The rock at the west end is about 30 feet above the general level of the land, and it extends horizontally for about 50 yards. On its east side the rock, though extremely tough, and full of large pebbles of quartz and other hard rocks, has been well smoothed by some agent of great weight and power which has come from the eastward.

The conglomerate rocks on the beach below the castle, present similar smooth surfaces facing the east.

Having learnt from the keeper of the castle, that smooth rock surfaces occur on a small island a few hundred yards to the east of Dunstaffnage, I procured a boat, and found two high knolls of conglomerate rock, as shown in fig. 4, smoothed in a similar manner.

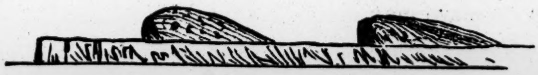


Fig. 4.

In going along the south bank of Loch Etive, one sees at numerous places great sheets of similarly smoothed rock, indicating, apparently, the action of a glacier which had moved down the valley now occupied by the loch. In the Fifth Report of the Committee (page 45), notice is taken of the Airde Point, on the west side of Loch Etive, where the rocks facing the south, *i.e.* up the glen, were found smoothed up to a height of 276 feet above the sea.

In passing along the new line of railway, between Oban and Loch Awe, one can notice many smoothed rocks, all like those before-mentioned, facing Loch Awe. A number of these smoothed rocks are covered by beds of fine gravel, sections of which, showing rock and gravel, are well seen on both sides of the railway which cuts through them. The best examples are near the village of Stonefield, to the east of Connal Ferry. The height above the sea here is about 40 feet, and traces of the well-known sea-terrace, so prevalent around the coast, are here observable. As one advances towards Taynuilt and Bridge of Awe, the detritus occurs in larger quantities. At Bridge of Awe it forms mounds, which are no doubt due to the removal of other portions of the detritus by the rains and streams descending the steep sides of Cruachan on the one side, and of the hills on the opposite side of the Etive valley. The Awe itself has on its banks, scaurs of detritus 20 to 30 feet in depth, and there are marks showing that the river has run in a different course and at a higher level.

The whole of this valley is full of boulders of granite, mostly grey, but occasionally red. These boulders generally lie on the detritus, and in many cases are covered by peat which has grown in the pools, or what had been pools, in the detrital hollows.

On ascending the hills on the west side of Bridge of Awe, which I did to the height of about 400 feet above the sea, I found boulders, especially on the slopes facing the north and east. They may, no doubt, have crossed the valley from Cruachan. I measured several of the largest, which were 5 or 6 feet in length by 3 or 4 feet in width and height. There were among them small boulders of well-rounded quartzite, which suggested a northern origin.

The large granite boulder on the roadside between Taynuilt and Bridge of Awe, nicknamed Sir Walter Scott, lies on detritus.

5. *Loch Sweyn.*—Having heard of some large-sized boulders in this neighbourhood I went there, accompanied by Mr Alexander of Loch Gilphead.

At Ardna, on the farm of Mr Macmillan, near Kilmory Bay, I examined a surface of smoothed slate rocks, covered by long and deep striations running W. by S. and E. by N. Unfortunately I omitted to observe from what direction the striating agent had moved, but as the smoothed surface of the rock sloped down towards the west, it is probable that the striating agent had come from the west.

On this smoothed and striated rock, there were large boulders of grey granite; I measured two, of the following dimensions, viz., 15 × 12 × 5 feet and 13 × 5 × 5 feet. Their longer axis was the same, viz., W.S.W. It is proper to remark, that the sea-lochs in this part of the coast occupy troughs which lie in a direction W.S.W. and E.N.E., and that the ridges of land which separate these lochs run in a similar direction.

The boulders and striated rock just mentioned are on the S.E. side of the ridge which divides Loch Sweyn from Loch Killesport. But on crossing the ridge north towards Loch Sweyn, I found most of the boulders on the hill slopes which face the N.W. all lying in the same manner, viz., with their longer axis parallel to the loch and to the ridge of high ground. On *this* slope, the boulders are in *thousands.* I measured a few of the largest,—one was 15 feet square and 8 feet high, another 18 × 7 × 5 feet. The ridge between the two lochs rises gradually to the eastward inland to a height of from 500 to 700 feet.

In this district I saw no detritus. If there ever had been detritus it had been swept off, as the rocks *in situ* were everywhere visible, and the boulders were lying mostly on the bare rock. Of moraines I saw no appearance. Sitting on this hill slope, and pondering from what quarter these boulders in such numbers could have come, it appeared to me that, in order to reach and remain on this hill slope, they could have come only from the N.W. If the agent which brought them, had come *down* the loch from the N.E. there was nothing to cause them to stop and remain where they now are;—they would have gone on towards the open sea at the lower end of the loch. If they had come from the S.W. there was nothing to obstruct their further progress up the loch.

In walking further up the loch, Mr Alexander and I passed a rock surface, pretty steep, and sloping down southwards, on which there were many deep striæ running W.S.W. and E.N.E., parallel with the general axis of the valley. The striating agent seemed to have come up the loch. This was at a place named on the Ordnance Map "*Doide.*" Here we obtained a boat and crossed over to *Danna Island,* to examine a large boulder which gives its name to the farm "*Danna na Cloiche.*"

The boulder would be of the shape of a pear, were a horizontal section made through its widest part (fig. 5). Its sharpest end

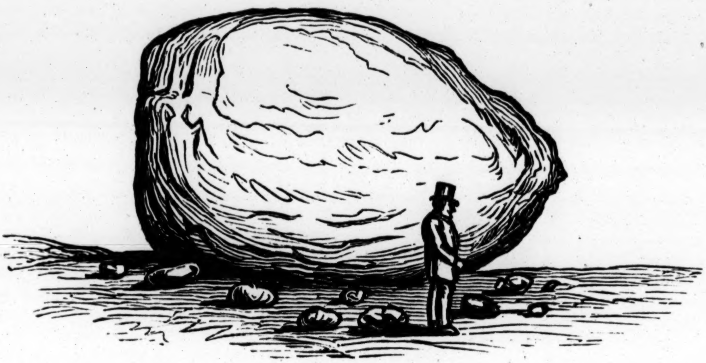


Fig. 5.

points S.W. Its height is about 15 feet, and it has three sides tolerably flat, each about 15 feet wide. I calculated its weight at from 60 to 70 tons.

Its axis coincides with the general direction of the valley, and its sharpest end is towards the sea, creating a presumption that something floating up the loch may have put it and left it in that position.

The boulder is nearly opposite to Castle Sweyn, which is on the south bank of the loch. There is a rocky knoll about 40 feet above the loch on which the castle had been built. On the west side of this knoll there is a great number of huge angular boulders, which seem to have come from the westward, and been intercepted by the knoll in their progress eastwards. The narrowest part of the loch is at Castle Sweyn, so that it was the most likely place for an obstruction of ice rafts from the west.

Mr Alexander of Lochgilphead, to whom the Committee are indebted for much valuable assistance in giving information about boulders on the west coast of Argyle, told me of a cluster of boulders on the farm of Taynish, about 4 miles to the south of Tayvallich, on Loch Sweyn. There is one large boulder from 9 to 10 feet high, surrounded by a number of small boulders. They lie on a bit of bare rock. The land slopes towards S.W. They are about 30 feet above the level of the sea, and distant from it about 300 yards.

Immediately to the east of the boulders there is a level plateau or beach, which may have been formed by the sea, when it stood at a higher level.

These boulders, Mr Alexander says, appear to have been transported from a S.W. direction. There are low hills to the northeastward, which probably obstructed them in their further progress to the eastward.

6. *Ardrishaig.*—In ascending the hill to the west, on the lands of Auchindarroch, accompanied by Mr Alexander of Loch Gilphead, I had pointed out to me by him a gneiss boulder, 9 × 7 × 6 feet, lying on a smoothed rock of clay slate. Its longer axis lay N. and S., its sharpest end being to the north. Another boulder, somewhat higher up, was seen, 16 × 13 × 6 feet, with its axis also N. and S. The slope of the hill here is down towards the S.E. These were at a height of about 300 feet above the sea.

On going higher up the hill and coming to a slope facing N.N.E., I fell in with many other boulders of such sizes as the following—9 × 7 × 6 feet, 8½ × 7 × 4 feet. These two were on the same slope, and one above the other, at a distance of about 15 yards. They must certainly have come from some northern point.

BERWICKSHIRE.

In July 1880, I was requested by Captain Norman, R.N., to examine some boulders which he had discovered in a ditch on a roadside situated about a mile to the north of Berwick-on-Tweed.

Having accompanied him to the spot, I found four boulders, each weighing from half a ton to one ton. Two of the boulders were of fine-grained granite,—one of them grey in colour, and the other with a shade of pink. They had most probably come from Cockburn Law, situated about 15 miles (as the crow flies) to the N.W.—the only hill of granite in this S.E. district of Scotland. The other two boulders were a dark porphyry. Lamberton Hill, situated to the N. and N.N.W., about 2 miles off, is composed of porphyry of several varieties. The site of these boulders is about 250 feet above sea-level.

BUTE.

1. W. J. Millar, C.E., Glasgow, having, during the last two years, had occasion to be frequently in Bute, and having taken notes of the boulders lying about the coast near *Rothesay*, and to the north of it, had the kindness to draw out for the Committee the following list of boulders observed and studied by him.

(1.) On the shore to the east of Rothesay, at Glenburn, a chlorite schist boulder 6 × 5 × 5, with large veins of quartz, weighing probably about 7 tons. It rests on the red conglomerate of this part of the island.

(2.) Near Craigmore pier, east of Rothesay, about 30 feet above sea-level, a boulder of very coarse pebbly schist, about 3½ feet long, well rounded and smoothed on lower side. It was near the mouth of a disused whinstone quarry, among conglomerate gravel.

(3.) Farther east, and south of a point of land a little below high-water mark, there is a boulder of trap, 6 feet long, resting on red conglomerate rocks.

(4.) On ascending the hill from the last-mentioned place, several micaceous schist boulders are met with, two measuring about 3 feet across, one about 70 feet, and the other 120 feet above sea-level.

(5.) Still farther up the hill, and on road towards Rothesay through a wood, at 150 feet above sea-level, there are many schist boulders, well rounded and smoothed, some about 3 feet in length.

At 180 feet above sea-level, there is a coarse schist boulder 5 × 2½ feet, one end round and smooth, the other end rough and angular —longer axis E.N.E. by compass.

(6.) Nearer Rothesay, on same road, at about 200 feet above sea-level—a mica schist boulder, about 6 feet long, rounded at one end and rough at other end.

(7.) In great sandpit above and behind Queen's Hotel, Rothesay, a mass of coarse gravel lies above sand, forming a bed about 12 feet thick. The underlying sand is of unknown depth, but a face of it is seen for about 30 feet vertically, with a length of about 200 yards. Several boulders of gneiss occur in the sand, the largest about 5 × 3 × 2 feet. North-west of this sandpit, and near it, there is a smoothed rock about 120 feet above sea-level. As its smoothed surface looks northwards, the smoothing agent must have come from some northerly point.

(8.) At Ardbeg, north of Rothesay, there are many boulders on the shore—one 9 × 8 × 5 feet, another 10 × 7 × 5 feet; one is quartz or chlorite schist, the other trap. The rocks *in situ* are chloritic slate, dipping S.E. 56°. First-mentioned boulder has its longer axis pointing N.W. and S.E.

(9.) Near the head of Port Bannatyne Bay, there are hundreds of boulders on the shore seen at low water, all well rounded. Those which are long shaped generally lie S.E. and N.W.

Near the head of Port Bannatyne, in a field about 30 feet above sea-level, there is a coarse schist boulder 4 × 2 × 2 feet, one side finely smoothed, with ruts on it parallel to longer axis.

(10.) At Ardmaleish Point (entrance to Kyles of Bute) there are many schistose boulders, some coarse and pebbly, others fine-grained. The largest is 8 × 8 × 6 feet. They lie on blue slate rocks.

(11.) At north end of Bute, opposite to Colintraive, the rocks, up to 230 feet above sea-level, are rounded and smoothed. They consist of mica schist, in some parts coarse and pebbly. Some of them quite resemble the boulders at and near Ardmaleish Point.

At 380 feet above sea-level, the rocks are smooth on their sides facing the N.W., but rough and fissured on their eastern sides. Blocks lie below them on these east sides.

(12.) Around Bull Loch, the rocks, at 560 feet above sea-level, are well smoothed, and form a steep wall facing N.W.

(13.) Notes applicable to district about 3 miles south of Rothesay:—

(*a.*) *Ascog Loch*, about 100 feet above sea-level; at north-east end, a great number of schistose boulders; at north-west end, a large quantity of schistose stones. The rocks *in situ* here are red conglomerate.

(*b.*) *Loch Fad.*—On the N.W. of this loch, there is a hilly range running N.E. and S.W., and reaching heights of from 400 to 450 feet above sea-level. In one part, there is a gorge through which something has passed, smoothing and striating the rocks. The striæ point S.E. and N.W. On the south slopes of this range, lie a number of blocks which seem to have been transported, being too distant from any cliffs from which they could have fallen by mere gravitation.

To the south of this hilly range, and perhaps an extension of it, there is a hill (not named in Ordnance Map) about 480 feet high on the north side of *Dhu Loch*. This hill on its north side presents rock-surfaces, rounded and smoothed. On its south slopes there are boulders, two of which I measured, viz., 6 × 5 × 2 feet, and 6 × 4 × 2 feet.

Close to *Dhu Loch*, there is another boulder, 6 × 5 × 4 feet, at about 320 feet above the sea.

The rock composing these boulders is apparently similar to that of the hills to the south of which they lie. What occurred to Mr Millar was, that they had been riven from the rocks of these hills by some agent, which passed over and across them from the north.

2. The Convener having in October last gone to *Rothesay* for a few days, examined several of the boulders on the east coast, mentioned by Mr Millar in the foregoing notes:—

One day was devoted, in company with Mr Millar, to a portion of the *West Coast north from Ettrick Bay*. A great many large boulders were found along the shore, showing transport from the north-west.

In Ettrick Bay itself, there are only a few boulders, and these are situated at the north side of the bay. The coast to the north of the bay runs in a line about N.N.W. by compass. To the south of that bay the coast-line runs about S.S.W. The position of the boulders is indicated on the annexed diagram (fig. 6) by × × ×.

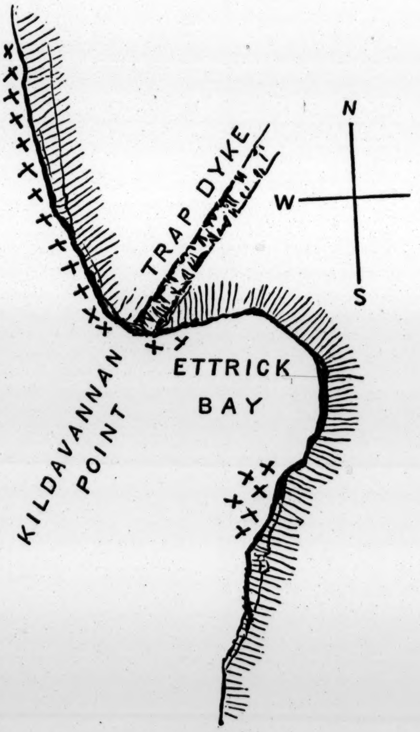


Fig. 6.

At the north end of Ettrick Bay, there is a compact ridge of rock, a sort of trap dyke, which stands from 10 to 15 feet above the adjoining surface of the land with vertical walls. The public road runs along the coast both north and south from Ettrick Bay, so that there is ample opportunity of studying the boulders lying on the shore.

At or very near Kildavannan Point a boulder of pure quartz first attracted attention, $6\frac{1}{2} \times 5\frac{1}{2} \times 4$ feet, weighing about 10 tons. From the way in which it was blocked on its east side, it seemed to us probable that the parent rock would be found to the west. Accordingly, at a distance of about 100 yards, a very large mass of quartz rock was found *in situ* among the slate rocks.

The boulder next met with was one of gneiss, $11\frac{1}{2} \times 7 \times 5$ feet, weighing about 30 tons. Its sharpest end pointed N.N.W. There was vertical slate rock under its east end, which seemed to have obstructed its progress eastward (see fig. 3, Plate III.).

There was another gneiss boulder $8 \times 7 \times 6$ feet, also on slate rocks, and blocked in a similar manner at its east end.

At one place the slate rocks, which are nearly vertical, and running in a direction about S.W. and N.E., presented a vertical wall on the beach of several feet in height, facing the north; a gneiss boulder, $12 \times 8 \times 5$ feet, weighing about 35 tons, rested against this north wall in such a way as to show it had been pushed from the north, and had been stopped by the rock. A number of smaller gneiss boulders were on the beach close to the north side of the slate rocks (see fig. 4, Plate III.).

Many more examples of the same kind were observed along the coast for about 3 miles. The boulders are larger in size towards the north.

On returning back to Ettrick Bay, a visit was paid to the coast, on the south side of the bay. It has been already mentioned that in Ettrick Bay, on the shore, there are no boulders, but to the south of the bay they again occur, most of them gneiss, though there are also some of granite. A sea-wall, lately built to protect the high road, contained a large number gathered off the shore, and others were showing their heads above water at a distance from the shore. The same agent which had carried or pushed the boulders along the coast north of Ettrick Bay, had continued its S.S.E. course across the mouth of the bay, and dropped boulders on the coast beyond the bay. The high ridge of rock at Kildavannan Point, before referred to, had probably to a certain extent protected the bay from any influx of boulders. If the transport of the boulders was due to ice floating on a current of the sea from N.N.W., this may have occurred when the sea stood several hundred feet above its present level, in which case the Kildavannan ridge might still have acted in the way now suggested, as it runs up the land, in a north-easterly direction, to a considerable distance.

All along the part of the west coast just described, the 40 feet old sea-margin is exceedingly distinct. Those at higher levels, seen elsewhere on the West Coast of Scotland, were not observed in this part of Bute.

3. On the following day the Convener, under the guidance of Mr Millar, paid a visit to *Barone Hill*, situated about 2 miles to the S.W. of Rothesay, and reaching to a height of about 530 feet above sea-level. Plate II., fig. 2, gives a sectional outline of the hill in an east and west direction. The hill was first approached by us from the eastward, and there was a close examination of the bare rocks on the north side in search of smoothed faces. One or two were found, though not of so decided a character as to deserve special notice. Beyond the principal hill, about half a mile farther west, there is another hill, reaching a height of about 430 feet, with a gully between the two, on which Mr Millar discovered markings of a very interesting character, and called to me to come and examine them. This gully is about 30 yards wide, having sides of bare rock more or less vertical—the rocks on the east side higher than on the west side. On entering this gorge (A figs. 2 and 3), it was at once seen that something had passed through it from the north, leaving unmistakable traces. What first attracted attention was the smoothing of the rocks at *d* on the principal hill, and on the opposite side of the gorge at *eee* (see figs. 2 and 3 in Plate II.).

On the west side of the gorge, the number of places ground down and smoothed are more numerous, one reason for which might be that the rocks appeared less hard than on the opposite side. On that side, there are some isolated patches of rock, well smoothed, because they had apparently encountered the full force of the agent which had passed through the gorge; but there are other patches, as at *f*, quite rough, because apparently under the shelter of others.

The ground in the gorge rises pretty steeply from the north, viz., about 100 feet to its summit-level at B.

On four or five masses of rock on the west side of the gorge, and at about its narrowest part, there are some remarkable striæ on the smoothed rock surfaces. Mr Millar measured several of the longest, and found them to be 12 or 13 feet in length. They almost all sloped up towards the south, and were several feet above the bottom of the gorge. The angles of slope were measured by a clinometer. The average was 20° to 25°, but one was found with an inclination up south of 43°. In two cases it was distinctly seen, that the ruts were deepest and widest at their north ends, thus Mr Millar found the rut, 13 feet long, was at its north end $1\frac{1}{4}$ inch wide, and $\frac{3}{8}$ths deep; another was 2 inches wide at its north end. These tapered to a point at their south ends. The graving tool, which had been sharp enough to cut deeply at first, becoming blunt by pressure on the rock, would naturally leave a smaller and fainter striation as it passed along.

These marks seemed to make it quite clear, that some powerful current had passed through the gorge, carrying fragments of rock and stones, and squeezing them up over the summit level. In no other way, would it be easy—indeed possible, to account for the smoothed surfaces at the sides of the gorge, and especially for the striations, sloping upwards, and cut most deeply at their north ends.

There were no boulders in the gorge itself; but on going to the summit level, and looking south upon the moors and hill slopes beyond, boulders were observed not far off, which may have come through the gorge, and been carried some distance.

There was no time that day, for further research. But Mr Millar kindly undertook, at some future period, to visit those parts to the south of the Barone Hill, and report on any boulders seen by him.

The result of his survey will be seen in the last part of the notes sent by him, already given. It confirms the supposition, that boulders were carried through the gorge, and were strewed over the hills to the south.

On returning to Rothesay by a route to the north of the principal hill, several small gneiss boulders were observed on a bit of flat land about 250 feet above sea-level. There also a portion of rock was discovered, consisting of strata nearly vertical, and ground down so as to form a flat surface. The edges of the strata were all abraded and smoothed in such a way as to show a passage over them of some hard and heavy body from the north.*

ISLAND OF COLONSAY.

1. *Notes by Mr William Stevenson*, 12 *Meadowfield Place, Edinburgh.*

(1.) The rocks of the island generally are of a slaty nature, in some places curiously bent or twisted.

There are also places where granite rocks occur, as at and near the small boat harbour of Scalasaig, on the east side of the island.

The rocks inland from the harbour are in a sort of glen, through which a road passes. The granite rocks are seen there.

The walls of the harbour are built of this granite rock. It is of a grey colour; but being somewhat soft in texture, it was faced with a yellow-coloured granite brought from Mull in ships.

(2.) On the west side of the island is Port Mor. It is only a bay. Its shores are thickly strewn with boulders of all sizes, up to several tons in weight. They are mostly covered with sea-weed.

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* Since this report was written, I have discovered a reference to the glaciations of this part of Bute, in a valuable paper by Professor Geikie, "On the Glacial Drift in Scotland," in the first volume of the Glasgow Geological Society's Transactions. The following extracts may be given, as confirmatory of what is said in the Committee's report:—

"A most wonderful exhibition of worn mammilated and striated rocks in this part of Scotland, occurs among the slate hills to the north of Loch Fad, one of a chain of lakes which nearly cut the Island of Bute into two. The hard silurian strata dip at high angles towards the S.E., and present in consequence their upturned edges towards the N.W. But instead of forming rough-rugged crags, as these rocks when left to themselves tend to do, the slates and grits are thrown down into the most perfectly smooth-faced knolls. The edges of the beds have been planed off obliquely. Moreover, on *Barone Hill*, the top of which is about 520 feet above the sea, the abrasion has been done by an agent which came up the steep northern face of that eminence, went right over its summit, and pursued its course down into the next valley beyond. The striations run from N. 15° W. to N. 20° E.

I was informed by Mr Donald M'Neill, a very intelligent farmer, long resident on the island, that many of the boulders in that bay resemble yellow Mull granite.

Mr M'Neill pointed out to me several boulders on his farm of Lower Kilchattan, which have distinctive names, some of them weighing from 2 to 3 tons.

He also spoke of a large boulder on the west shore, about a mile to the south of Port Mor, between Dun Gallon and Ardskinnish, called Fingal's Putting-Stone.

He mentioned that at Kiloran, on the north-west part of the island, there is a sandy bay which leads to another bay called Port Shipness, where there are many boulders.

Some large boulders are said to lie on the small islands to the east of Oronsay Island, where the old cathedral stands.

On several ridges of Colonsay, sloping towards the west, boulders occur, as at Mullbuie and Schoolhouse Brae. Those on Mullbuie are about a ton in weight.

All the hill tops are smoothed. On *Carnan-re-Erium*, the highest hill in Oronsay, there are said to be tracings of ice-markings; but I had not time to search for them.

In different parts of the coast there are shingle beaches composed of well-rounded, whitish-coloured hard stones, about the size of a man's head, and under. Ships come sometimes to take away these stones, to be used for paving-stones.

2. *Notes by Mr Donald M'Neill, Lower Kilchattan, Colonsay.*

(1.) At the north-east of the island, on the farm of Balnahard, there are granite rocks.

At Scalasaig there is granite rock on the shore, and not far inland.

The granite rocks in Colonsay are everywhere of a dark grey colour.

(2.) The yellow granite used for building the harbour at Scalasaig was brought from Mull by ships—a distance of about 12 or 13 miles.

(3.) There are boulders in various parts of Colonsay.

Those which are granite are (in my opinion) foreign to the island, being of a lighter colour than the rocks of the island. By some unknown means, they have been brought to where they now lie.

(4.) There are boulders of granite, whinstone, and quartz. Those of granite are generally on hill tops.

Those which I mostly noticed, are lying on hill tops and slopes of hills. There are also a number along the shore, on the west side of the island.

(5.) The boulders like paving-stones are mostly on the north and west sides of the island, along the shore.

They are all rounded, and of an oblong shape generally, from the size of fine gravel, till some would rank amongst boulders. The highest bank of these heaps of paving-stones above the sea shore that I know, will be some 80 feet.

The Colonsay shingle beaches are the same as Jura's for nature of the stone; but I believe Jura's are longer in extent, but not any higher above sea-level.

(6.) The Putting-Stone of the Fingalians lies on the sea side of Ardskinnish. It is one of the largest boulders in Colonsay. I believe it is whinstone, and weighs some 4 tons at least. It is round in shape. Tradition says the Fingalians used to throw it across the bay from where it lies, to Dungallon on the opposite side.

The boulders that I am mostly acquainted with, are on hills sloping towards the south.

Boulders are lying on Colonsay's highest hills. I don't know how high above sea-level they are.

The foregoing notes, though supplied by gentlemen, neither of whom has geological knowledge or experience, appear to me exceedingly valuable. They show that on Colonsay there are boulders well deserving of study, in order to ascertain from what quarter they have come. From the fact stated by Mr Stevenson, that many boulders lie on hill sides sloping towards the west, it is probable that the boulders came from some westerly point,—perhaps from the Island of Mull. But by an examination of the manner in which the boulders have been set down or placed, by the agent which brought them, a conclusion on this point may be arrived at.

The thanks of the Committee are due to Mr Stevenson and Mr M'Neill for their attention to the Convener's application to them in this matter.

LINLITHGOWSHIRE.

1. Two years ago, the Convener, having been kindly invited by Mr James Melvin, tenant of Bonnington Farm, to examine some boulders near his farm, went there under his guidance.

On *Pumpherston* Estate there is a bit of ground higher than any adjoining district, on which there is still a considerable number of boulders, though formerly there were more. The height of the spot is about 430 feet above the sea.

The largest goes by the name of the "*Ballengeich Boulder.*" It is in girth 10 or 12 feet. The spot on which it lies is about 3 feet above the adjoining ground. The boulder, though at one time an entire mass, now consists of eight fragments. How it has been broken, and when, is of course matter only of conjecture. It seems due to some natural cause. It may have been caused by atmospheric action, or by falling from a height.

It is evidently an erratic,—being a coarse dolerite—of which there are no rocks known nearer than the Bathgate hills to the N.W.

The eight fragments combined would produce a mass of from 50 to 60 tons.

Mr Maclagan, M.P., the proprietor of the land, having been so obliging as to send a labourer with a pick and spade, a pit was dug in two places adjoining the boulder to ascertain the nature of the substance on which it was lying. Boulder clay of a blueish yellow colour was below. The block had sunk into it about a foot.

2. Not far from this boulder there is another, about a quarter of a ton in weight, of quartzite with crystals of green mica, most probably from the Highlands.

The other boulders were smaller in size, and of ordinary trap,—a rock abounding in many of the adjoining hills.

3. On the farm of *Bonnington*, there is a boulder known as the "*Witch's Stone,*" about the same size as that on Pumpherston, at a height of about 431 feet above the sea.

It is on *Tornain Hill*, and on a slope, which faces W.N.W.

It is a dolerite, though not so coarse as that on Pumpherston.

Mr Melvin had an excavation made under the boulder, and ascertained that it rested partially on the trap rock of the hill; this rock, however, being different in composition from that of the boulder. The nearest rock of the same kind, known to Mr Melvin, he stated to be in the Bathgate hills, situated about 5 miles to W.N.W.

There is a valley between these hills and Tornain Hill, across which the boulder must have been transported.

This boulder, like that at Ballengeich, has been broken, and consists of six fragments. The principal mass lies to the west of the fragments, as if they had been broken off by some force from the westward; or they may have been broken off by concussion if the original mass fell from a height.

The fragments have certainly not come off at any recent period. Judging by their surfaces they look quite as ancient as the principal mass.

The principal mass is well rounded on all its sides, suggesting much rough treatment ere it reached its site.

Some interest attaches to the boulder on account of a set of "cup markings" on it, of which an account is given by Mr Smith in a late volume of the "Transactions of the Scotch Society of Antiquaries."

It is right to add that if a line be drawn from Tornain Hill to the Bathgate hills, it passes close to the site of the Ballengeich boulder.

4. Mr Melvin mentioned to the Convener that, on the S.E. side of this Tornain Hill, there was once a dolerite boulder (which he had seen) measuring 21 × 5 × 4 feet, lying with its longer axis E. and W., and at a height of about 300 feet above the sea.

If it came from the Bathgate hills (which was probable), it could, in his opinion, have come only by floating ice, through the valley between Tornain and the Crow hills, *i.e.*, from the westward.

5. Mr Melvin further informed the Convener, that in the channel of the River Almond, below Kirkliston, there is a boulder of Old Red Sandstone conglomerate,—the nearest parent rock of which was probably the well-known belt of conglomerate crossing

Scotland in a N.E. direction from Dumbarton. This conglomerate boulder, $5\frac{1}{2} \times 4\frac{1}{2} \times 4$ feet, had its corners well rounded. The nearest point to the parent rock *in situ*, would be at or near Callander, a distance of about 40 miles, in a direction about N.W., with several ranges of hills and valleys intervening.

6. Mr Melvin, at Ratho Railway Station, drew the Convener's attention to the greenstone rocks there, how they are well rounded and smoothed on their sides facing the W. whilst on their sides facing the E. they were rough.

He also pointed out how, on several of those smoothed surfaces, there are numerous striæ and ruts running in a direction W.N.W. and E.S.E. (magnetic).

Portions of these smoothed and striated rocks are covered by boulder clay or till, containing many small boulders and hard pebbles, which, by passing over and pressed down on the rocks, might have produced both effects.

A number of large trap boulders were lying about. The largest examined, weighing between 2 and 3 tons, has horizontal striæ on its side, which faced N.N.W. These striæ might have been formed by a force coming in a direction from W.N.W. and striking obliquely on that side of the boulder.

This locality is at a height of from 180 to 190 feet above the sea.

NOTES BY PROFESSOR FORSTER HEDDLE, OF ST ANDREWS UNIVERSITY.

LOWLANDS.

In April 1880, whilst there was still so much snow on the Highland hills as to render explorations on them impossible, the Professor went to Dumfriesshire, having received notice of two boulders among the Wanlockhead hills.

(1.) The first he examined, called "The Crooked Stone," lies in a field on the right bank of the Clyde, about 3 miles above Elvanfoot Station. The stone protrudes above the surface about 5 feet. Its width is nearly 5 feet; its thickness about $1\frac{1}{2}$ feet.

It is on a knoll projecting somewhat above the adjacent river-terrace.

The rocks about *in situ*, are Greywacke. The boulder is also Greywacke, but much more gritty than any of these rocks in its neighbourhood.

In walking some distance up the valley, at the mouth of which the boulder lies, gritty rock, similar to that of the boulder, was met with on the slopes of Dunlaw Hill.

(2.) The other boulder lies within a field on the north side of Cranwich Water, about half way between the farm of Crossbank and Spango Bridge.

This stone protrudes about 4 feet above the ground,—and is nearly rectangular, the breadth of the sides being each about 2½ feet.

It is a Dolerite, formed of platey augite in large crystals, with very little felspar. It has an unusually rough surface. It differs from any rocks in the neighbourhood, but resembles the rock of three Dolerite dykes which cross the country some miles to the north.

(3.) To try and discover the parent rocks of these boulders, a walk was taken along the central ridge of the Lowthers, as well as along several of the spurs and valleys stretching on the one hand to the Clyde, and on the other to the Nith, but without result.

To save trouble to future explorers, it may be mentioned that the following hills were ascended, viz., Lowther Hill, Green Lowther, Dungrain Law, Dunlaw, Hawk Wood, Broad Law, Hunt Law, Slough Hill, Stoor Hill, Glen Gober Hill, Low Mill Knowe, Clockhill Hill, The Dods.

HIGHLANDS.

For the reason just assigned, the Professor notes in detail the various mountains visited, though no boulders were found on them. He observes, that had this practice been followed by previous geological surveyors, he would probably have been saved many a toilsome climb during the last two years.

But he states an additional reason for indicating the mountains where no boulders were discovered.

From last year's Report it will be seen, that he had observed, in at least two districts of Argyleshire, distinct "*streams of boulders*," while the districts adjoining these streams contained none.

The fact of there being two such streams, suggested the probability of there being others; so, as both of these streams indicated a direction about east and west, he resolved to cross the country in a north and south direction elsewhere, at the same time following, as much as possible, the ridges of the hills lying that way, and climbing to the summits, for the sake of having an extensive view. Being accompanied in this expedition by two or three friends, each provided with a binocular, it was not likely that boulders of any size, visible within half a mile of the route followed, would be missed.

Professor Heddle carried with him an Ordnance map with contour lines, which at once indicated the heights of the hill ranges, and on these he has drawn, with a thick red line, the exact route taken. This map he has sent to the Convener. To him it has been of much service by enabling him to follow the Professor's notes.

But, before specifying the names of the hills visited, and the results, it is not unimportant to notice some remarks by the Professor of a general nature bearing on the best way of boulder hunting.

He states that former explorations had impressed upon him the advantages of making a search chiefly along hill ridges, and of scaling hills to their summit. In the *first* place, a more extended range of observation is obtained, and in the *second* place there is more probability of finding the boulders in their original positions.

If boulder hunting is carried on in glens or valleys, as has hitherto usually been the case, the range of observation is exceedingly limited;—whereas, from a hill top, a panorama of a wide range of country may be obtained, which, besides showing boulders, makes the gradients of the country more intelligible, and indicates where there may have been passages for ice, whether land or sea ice.

Another advantage is, that if boulders are met with on hill tops or hill ridges, it is almost certain that they occupy the position in which they were originally placed by the agent, whatever it was, which brought them. But boulders in a valley, or on the sides of a valley, may have rolled down from a higher level, and thus afford far fewer data for safe reasoning.

Professor Heddle observes that there are ranges of hills of considerable elevation, more or less continuous, which stretch northward, commencing near Rowardennan, to the south of Ben Lomond, and reaching to the neighbourhood of the Dochart and Loch Tulla, where the stream of boulders was first recognised by him in the previous year.

1. This accordingly was the general line of route he decided to take, and the following is a diary of his explorations.

First Day.—Rowardennan to Inversnaid, by *Ben Lomond* (3192 feet).

Near Rowardennan, much appearance of glaciation along banks sloping to the loch, showing a southerly movement.

A dyke of Diorite strikes eastward above Rowardennan to a height of about 450 feet. A few small blocks from this dyke lie a short distance from it on its south side;—but there are none on the north side.

At the foot of the north slope of *Ben Lomond,* a very unusual and characteristic Greywacke rock *in situ* was noticed. It contains nodules of milk-white quartz larger than almonds. It will be referred to when an excursion along the Ochils comes to be mentioned.

No noticeable boulders were found.

Second Day.—Crossed Loch Lomond, and went along the whole ridge of *Ben Vorlich,* and over its two summits (3092 and 3055 feet) on to Inverarnan. *No boulders were seen.*

Third Day.—Ferried the River Arnan, and went along the terribly rough ridge of *Ben-a-Chabair* (3054 feet); then down into the col between it and *Ben-a-Chastle;* then up to the top of *Ben-a-Chastle* (3265 feet); then down along its ridge (where saw the *Brocken,* for the second time in Scotland) to Crianlarich. *No boulders.*

Fourth Day.—Went over *Crag Loisgte* (2750 feet), *Ben Challum* (3354 feet), down to Strath Lochy; then over *Stron-nan-Eim* (2747 feet) and *Creag Mhor* (3387 feet); then, down into the col between its second top and *Cam Chreag* (2887 feet); next, over the latter into *Glen Choilleun,* then, over *Beinn Odhar* (2848 feet) and down its ridge, back to Crianlarich. *No boulders seen.*

But in the col between the second top (name not given in inch map) of *Creag Mhor* and *Cair Chreag,* some interesting and puzzling appearances attracted attention, which the Professor says he had noticed in other parts of Scotland.

At the very head of the col (2480 feet), just where it folds over to the watershed, where streams rise to flow in opposite directions, "there are numerous heaps of gravel similar to what are known among the Swiss glaciers as '*dirt cones.*' These were higher and larger in the sides of the trench than in its centre. They continue but a short distance down the valley on each side, diminishing in size towards the lower levels."

If "*dirt cones*" (as is generally alleged) be formed by running water on the surface of ice, carrying stones over the edges of the crevasses and depositing them at the bottom, may it not be inferred that there was a mass of ice here which, at the col, broke into two divisions, forming a glacier for each valley?

(The Professor remarks, that this was the second hardest walk during one day which he ever took, the distance travelled being 26 miles, and the amount of ascent being 7900 feet.)

Fifth Day.—Returned to re-examine the col, going by the valley between *Ben Chaluim* and *Ben-nan-Marsen* to top of *Creag Mhor's* second top, then over the col to *Cram Creag*, and back by *Glen-a-Clachain.*

No boulders seen.

Sixth Day.—From Tyndrum over *Ben Doreann* (2523 feet) to Inverarnan. *No boulders* were seen, except some mentioned in last year's Notes (these apparently omitted to be noticed in last year's Report), near the bridge over the Orchy.

Seventh Day.—Examined the sides of *Ben More* (3843 feet), *Stob Luib*, and the trench of the Dochart. Found the highest glacial markings to be upon *Stob Luib* at a height of 750 feet above Luib Railway Station.

From the material of the till, and the closed nature of the country, the Professor concluded all to be due to a local glacier rising in *Ben Laogh*, and largely fed from *Ban-nan-Imarean* (2769 feet) and other hills north of the Dochart; the glacial striæ on *Stob Luib* pointing more to these hills than directly up the glen. *Ben Laogh* bears W.N.W.

Eighth Day.—Went over *Ben More*, *Am Binnean* (3827 feet), *Stob Choire an Lochan* (3497 feet), *Am Mam* (2500 feet) *Meal Monachyle* (2122 feet), down the *Braes of Balquhidder* to Loch Earnhead. No boulders and no glaciation over the great col between *Ben More* and *An Runican* (2800 feet) were seen.

Ninth Day.—Went over *Ben Vorlich*, then over *Stuch a Chroin*, *Meal Odhar*, to Callander. *No boulders.*

Tenth Day.—From Callander over *Ben Ledi* (2882 feet); a hill ridge to *Ben Vane*, and down to *Strathyre. No boulders*, except some of gneiss near Callander. (On three of these days Professor Heddle was alone, on the others he was accompanied by a party of never smaller than four. The sides and ridges of the hills were swept by binoculars.)

Professor Heddle's notes next mention his return to Arrochar, and on the *first* day ascending the *Cobler* (2400 feet), making the circle of its summit, and descending to the col between *Ben Narnan* and *Beinn Ime* (3318 feet), and returning by the valley between *Ben Narnan* and the *Cobler.* He observed glaciation (ill-defined) passing north-eastward. There were a few rounded blocks of Syenite lying on the col, which seemed to have been moved in a north-easterly direction, from veins of that rock in the col.

On the following day he ascended *Ben Narnan*, through and by the sides of what he terms a "*Cradle Cup*," to its summit, and then down to the col between it and *Ben Ime*, over its summit to the col between it and the north hill (name unknown), down by *Choiregrogain* and back by *Glen Loin.* Boulders of the same Syenite were seen on several parts of *Choiregrognain.* Several veins or dykes of this Syenite were found, especially a very large one protruding from the north shoulder of *Crois* (2785 feet). Assuming that the boulders came from these dykes, they had by some agency been transported eastward.

The "*Cradle Cup*," lying between *Crois* and *Ben Arnan*, is described as "an elevated and confined little valley," with a rocky dam, which if *nevê* was formed there, might have retained it long enough to allow of it being converted into ice, supposing the climate to have been suitable. Not even in the contracted portion of valleys, is there so marked an amount of grinding, grooving, and polishing seen, as was seen upon the inner side of the rock dam of this "*Cradle Cup.*" These evidences of ice action, at an elevation of only 1500 feet above the sea, are all the more remarkable, on account of the total absence of glaciation throughout the whole sweep of *Choiregrogain* from its extreme altitude of 1700 feet down to the level of Loch Long.

The manner in which this little *Choire Sugach* is shut in from the *west—first*, by the spur which connects *Ben Narnan* with *Crois;* and *secondly*, by the towering bulk of *Ime* to the back of this; and *thirdly*, the palpable shedding of its ice to the eastward, out of a hollow surrounded with craggy and rough-edged rocks, and in a district which nowhere else shows glacial action, is unfavourable to the supposition that the ice which had been grinding the rocks had come either from any floating sheet from the west, or from any enveloping mantle from the east. The parts here seem to show that though elsewhere there may be examples of either or both of these agencies, there is evidence that the temperature of the country was at one period such that glaciers, however small, were generated and cradled among its hills.

From *Arrochar* Professor Heddle walked across the range of hills towards *Loch Goilhead*; one day was spent in visiting *Loch Restil* and *Ben Lochan* (2955 feet). On the following day he went up *Corry Corran;* then, over the shoulders of Beinn Lochain (2304 feet); then, into the trough of *Corry Lochain;* over the ridge and top of *Beinn Bheula* (2557 feet); over the north shoulder of *Cnoc na Trieriche*, down to *Lochan nan Cnaimh*, over *Crauch nan Miseag* (1989 feet) and back to Loch Goilhead by the shore. No boulders, moraines, or traces of glaciation were seen during these two days.

Professor Heddle, on a review of the whole of the foregoing explorations, states that the South-Western Highlands appeared to be singularly barren of boulders at high elevations, and that the only traces of ice afforded evidence of glaciers of small size, formed in some of the valleys and hollows among the higher hills.

He thereafter decided to return to the more northern district of the Highlands, where in the previous summer he had met with boulders of large size, not only perched upon ridges, but forming streams, stretching for miles continuously.

As one of these streams had been found on the Moor of Rannoch, and extended eastward to and beyond Loch Tulla, he went to Fortingall, that he might from that point follow the chain of hills which block more or less the moor at its eastern end.

The course lay over *Ben Dearg* (2000 feet), *Creag Mhor* (3000 feet), an unnamed hill west of this (3240 feet), *Carn Mairg* (3419 feet), *Malharran Odhar* (2230 feet), *Geal Charn* (2595 feet), *Creag Mhor* (2250 feet).

Nothing was discovered on any of these hills till *Geal Charn* was reached. After the top of it was passed, and about 400 yards beyond it, at the height of 2498 feet, two boulders were found, about 100 yards from each other, and weighing each about 7 tons. This hill of *Geal Charn* with *Creag Mhor* to the north, forms a continuous ridge running nearly north and south, crossing therefore the great central trough, of which the Moor of Rannoch forms part, the general level of which moor is not more than from 900 to 1000 feet above the sea. If, as the explorations of the previous year showed, boulders had been dropped by some means from the west along Rannoch Moor in the form of a stream, none were likely to be found on any of the hills to the south of *Geal Charn*, as these hills were blocked by higher hills to the west, such as *Meall Garbh* (3048 feet) and *Meall Bnear* (2291 feet). On xamining the rock composing these two boulders, Professor Heddle was of opinion that it was the same as that of the boulders lying near Loch Tulla, and which he had tracked, from one hill to another, till a rock *in situ* the same in composition was found on the high hill called *Albannach*, about 12 miles to the west. The only difference which he could detect was, that the rock of the *Geal Charn* boulders was "somewhat of a coarser grain."

Conceiving that this hill of *Geal Charn*, by lying transversely across the trench, had caught some of the boulders, it occurred to Professor Heddle, that as the loftier mountain of Schehallion, situated about 3 miles to the east, was also in such a position, that it may have intercepted some of the Albanach boulders, he ascended it on the following day.

He had not much expectation of finding boulders on it, as it forms an elongated range in a nearly east and west direction. However, when he was about 140 feet from the summit (that is 3407 feet above the sea), he did find at its west end, a boulder of Albannach granite, of about three-quarters of a ton in weight.

Professor Heddle states that he looked about for more granite blocks, but did not fall in with any. The sides near the top, especially on the north side, he says, are covered by "loose blocks of the porcelain porphyry of which the hill is formed."

The Convener can on this point supply information obtained by himself some years ago, on the occasion of his ascent of Schehallion. He gives the following extract from his geological diary :—

"1872, August 27.—Went up Schehallion, in company with Principal Shairp of St Andrews and Professor Blackie. We began ascent at $1^h\ 50^s$, and reached summit at $5^h\ 10^s$.

"We went up by a ridge of the mountain running east and west. The height of hill I made by aneroid, 3450 feet. I believe Professor Nicol made it 3561.*

"For the first 1000 or 1500 feet, from where we began our ascent (at Braes of Forss) on east side, beds of sand and gravel were observed. Near the top, there were quantities of small pebbles, apparently fragments of the hill rock, which is a sort of hard sandstone, somewhat like quartzite. Near top, *observed a few small granite boulders.*

"The upper part of the hill, especially on side facing N.W. by W. (magnetic), was comparatively smooth, but saw no striations. On that side, however, the angles were more rounded than on any other side.

"On descending, we did not return along the ridge or back-bone by which we had ascended. We slanted down in a S.E. direction. On the way, I noticed *various granite boulders,* but none exceeding a ton in weight. I chipped some, and found them to be all a fine-grained gray granite. These were most numerous, at a height of from 2000 to 3000 feet above the sea.

"Observed also in our descent, that there were smoothed rocks, and chiefly at a height of about 2500 feet. I was struck with the fact, that I saw no smoothings *above* that height.

"Observed in the banks of the burns flowing down the south side of Schehallion, high cliffs of boulder clay, at a height of about 1200 feet above the sea.

"On showing my chips of the boulders to Principal Shairp, and asking if he had ever seen elsewhere rocks of a similar composition, he said he had been at Loch Sunart last year, and had noticed granite rocks there very similar to that of the boulders."

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* By Ordnance Surveyors it is made 3547 feet.

The contour lines on the ordnance map indicate that the longer axis of Schehallion runs about W.N.W. and E.S.E. It has a large flank facing the W.S.W., which could, therefore, readily intercept any boulders brought from any point between S. and W.N.W.

Since the foregoing paragraphs were written, I have found further proof of there being granite boulders on Schehallion, in the following extract from a paper by the late Robert Chambers in the "Edinburgh New Phil. Journal for 1855" (vol. i. p. 101).

"Schehallion is composed of quartz rock. It is abrupt to the west, and tails away to the east. I found surfaces at several places bearing that peculiar streaking which I had remarked as a glacial phenomenon peculiar to quartz rock, on the mountain of Queenaig in Assynt. At about the height of 2200 feet above the sea, there is a fine group of examples. There is another similarly striated or streaked surface, a few hundred feet below the summit of the hill. The *direction of the striation* in both instances is W. 30° N. About 800 feet below the summit, I found *a block of granite*; and in several other places there are blocks of other rocks, likewise different from those of which the hill consists. From all I have seen, I entertain no doubt that Schehallion owes its form to a glacial agent, which has engulfed the whole range."

These observations by Dr Chambers and me confirm Professor Heddle's statements:—*first*, as regards the existence of granite boulders on Schehallion; *second*, as regards the direction of the stream which brought them; for there can be little doubt that the transport of boulders and the striation of rocks on such an isolated mountain as Schehallion can be well accounted for by the same agency.

The result of these explorations in the Black Mount district has, therefore, been to confirm the correctness of the conclusions come to in the previous year, that boulders had been strewed over the district in a sort of *traînée* from Albannach Hill in an easterly direction, and that portions of the stream had reached Schehallion. Some of these boulders were in last year's Report stated to have been found at a height of 2530 feet above the sea. This year's explorations showed them in positions 2498 feet (on Geal Charn) and 3407 feet (on Schehallion) above the sea.

Albannach Hill reaches to a height of 3425 feet above the sea.

Some hesitation may be felt in assuming that the boulder on Schehallion, being only 18 feet below the highest summit of Albannach, could have come from Albannach; but it is quite possible that Albannach Hill may, since the boulder epoch, have been lowered by denudation.

A sketch of the Rannoch district is given on Plate IV., with red dots to show the positions of the boulders seen and identified by Professor Heddle.

Professor Heddle adds, that having heard that other observers had found boulders on Schehallion, and which were supposed to have come from the Ben Aulder district, he thinks it right to mention that there is in fact no granite in the hills of that district, except at one locality, where Prince Charles's Cave is situated, at which place the granite is composed of crystals an inch or more in size, by which it is quite distinguishable from the boulder he found on Schehallion, and from the Albannach granite.

2. Another district examined last year by Professor Heddle, was both banks of the Linnhe Loch to the S.W. of Fort William.

It will be seen from last year's Report, that at two places, there were appearances for which he could not account, except on the supposition that some agent had brought boulders across the Linnhe Loch, from the district of Glen Tarbert, to the districts at the head of Glen Crerar and Glen Etive.

In order to seek for symptoms of glaciation in the Glen Tarbert district, Professor Heddle last year crossed by the Connal Ferry.

That glen, and several hills and valleys adjoining it, were examined with little success. Boulder clay only was found, viz., in Glen Tarbert itself.

At length a valley called *Coir Syveamhael,* running in a N.W. and S.E. direction, was found "tremendously glaciated" between the altitudes of 950 feet and 1550 feet.

Marks of glaciation were also strong between *Meall Challium* and *Meal-a-Chairean Zuachraid.* These marks showed movements not only over the col (1680 feet) but for a certain distance up the north slopes of Meal Challium, the rocks of which had been powerfully acted on. The course of the ice, judging from the smoothings of these rocks, seemed to have been from W.N.W.

The glaciation extends down into the valley called *Coire Meall*

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RANNOCH BOULDERS

(Red dots indicate Boulders seen.)

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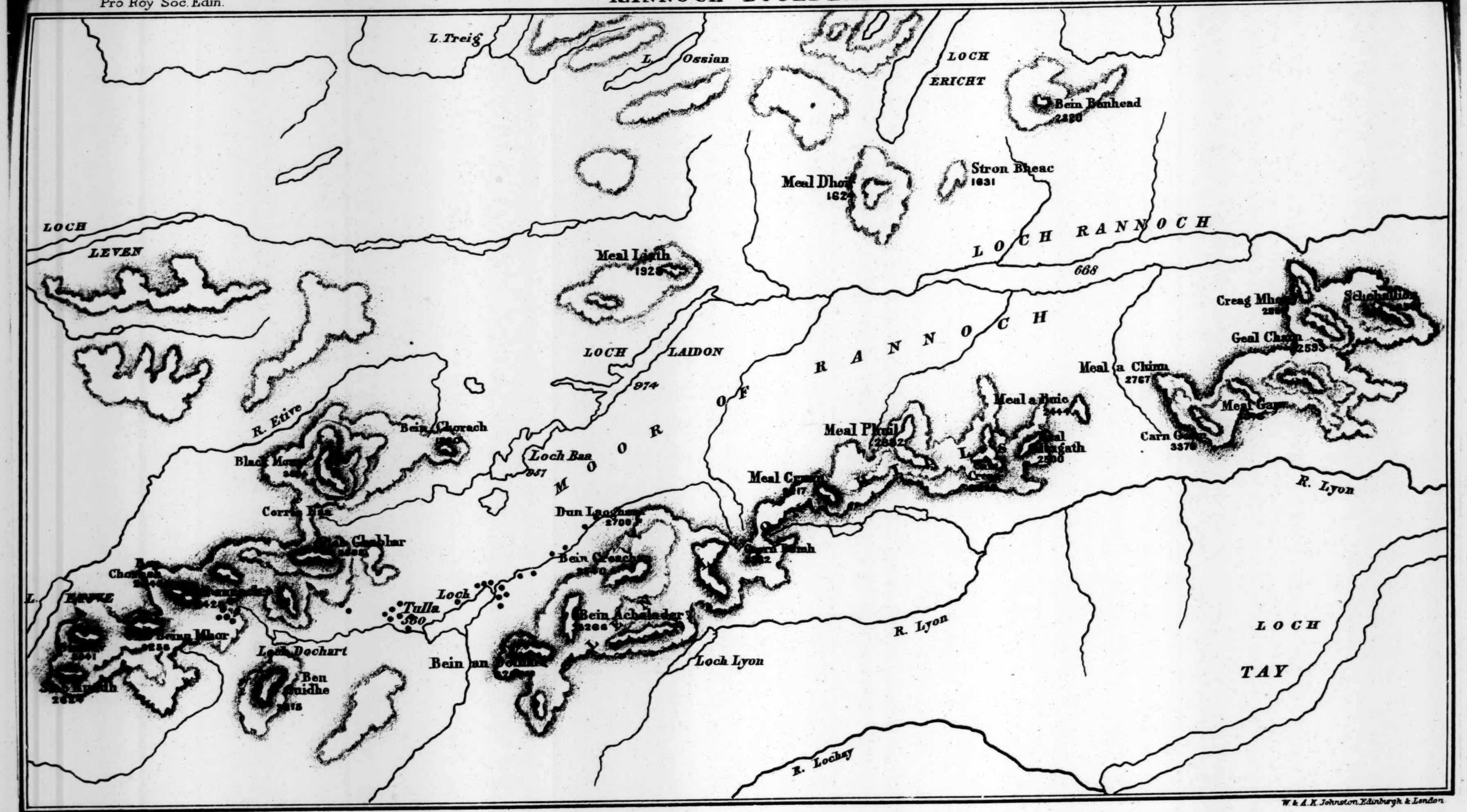

(Reduced from Ordnance Survey Maps.)

W. & A. K. Johnston, Edinburgh & London.

Challium, the sides of which are so marked, down to a level of about 950 feet.

No boulders were found on these hills or in the valleys.

From these glaciated hills a view across the Linnhe Loch was obtained; and in particular, looking along the groovings of the rocks on the sides of *Coire Maell Challium*, the eye catches a sight of the trench of the *River Durer*, and hits upon "the very spot in the small *col* in the spur of *Fraochaidh*, where, at almost the same altitude, glacial *striæ* were observed in 1879."—(See p. 42 of last year's Report.)

3. Another set of hills visited on the north side of the Linnhe Loch are those embracing *Glen Conar*. Having followed up the glen for 3 miles without finding boulders or marks of glaciation, Professor Heddle states that he struck off by hills marked on the ordnance map, *Sgur an Lubhair*, *Stob Coire Riach* and *Stob Choire a Chearchaill*. On the last-mentioned hill, he found so remarkable a *traînée* of boulders that it at first occurred to him they might possibly have been derived from a natural dyke or vein which had disintegrated. He searched carefully for such, but could see no traces of any. The boulders—for such he now considered them to be—lay on and along a ridge of the hill for nearly a mile, at heights varying from 2400 to 1800 feet, below which last level none were found. The directions of the *traînée* was N.N.W. and S.S.E. The boulders were generally not larger in size than a cubic yard, and consisted mostly of a peculiar syenite with some of the felspar crystals of a red colour, and with hornblende of a lively green colour. He counted nineteen boulders of that kind. There were also other boulders interspersed, of ordinary syenite, gneiss, and trap.

As it appeared, to him that the ice which brought these boulders had crossed the Linnhe Loch, Professor Heddle next visited several hills on the opposite or south side of the Loch, in hopes of discovering boulders of the same peculiar syenite. One of the many hills visited was *Bein Bhan*, reaching to a height of 1500 feet. The rocks in this hill are of clay slate, and at its summit, on the east side, there is quartzite with embedded crystals of hornblende. Another hill, not far off, is *Beinn na Gucaig*, reaching to a height of 2017 feet, composed of quartzite overlying clay slate.

On both of these hills, boulders of the peculiar syenite seen on the *Stob a Chearchaill* ridge were found, up to their respective summits.

On the *Bein Bhan* hill a ridge runs up from the north-east towards its summit, on which ridge one of the boulders was found in so peculiar a position, that a sketch of it was taken, the shading being filled in by Mr Colin Phillip (an artist) who accompanied Professor Heddle. (Plate III., figs. 5 and 6).

The boulder consisted of six pieces, the smallest being lowermost. The question arose, What had fractured the boulder? Atmospheric action did not seem the agent. The surfaces of the fragments where rent, were somewhat conchoidal in shape, and indicated rupture by violence done to the under part of the boulder. The most probable explanation which suggested itself was, that it had tumbled off the raft which carried it, and, being of great weight, had broken by concussion against the rock of the hill. The size of the boulder was 8 × 7 × 6 feet.

If this boulder formed part of the stream which had crossed the valley now occupied by the Linnhe Loch, it must have been floated on ice,—in which case the fall of the boulder would be through water. At the sea-bottom, the concussion upon rock might still produce a fracture of the boulder; and the fragments would remain closer to one another, than if they had fallen in air.

A representation of the hill ridge on which the boulder rests, and of the fragments composing it, is given on Plate III. fig. 5, and indicates the position of the boulder on the N.E. ridge of the hill. Fig. 6 represents the boulder in its different fragments lying on a notch of the hill.

The Convener who has made the foregoing extracts from Professor Heddle's notes, thinks it only due to him to mention that these extracts give no idea of the enormous amount of labour which the Professor has undergone in his boulder researches. During the summer and autumn of 1880, he must have walked several hundred miles over districts many of which are not accessible to ordinary pedestrians. This is shown by the tracks of his surveys laid down by him on the ordnance maps, and by the names given in his notes of the hills and valleys visited. A great part of these expeditions were unsuccessful and disappointing; but he has specified them in full detail, in case the committee might deem it useful to record in their Report the districts visited, for the information of future observers.

The Committee, at a meeting held on 24th June 1881 for the adjustment of the Report, where Professor Heddle's notes were shown, and some portions read to the Committee, were of opinion that they had been too much abbreviated by the Convener; and they requested him, on revising the proofs of the Report, to give more copious extracts, which accordingly has been done.

NOTE BY RALPH RICHARDSON, Esq.

Loch Skene.—A letter from Mr Ralph Richardson to the Convener, dated 11th March 1881, gives an interesting account of boulders, at a considerable height, near Moffat:—

"*R.S.E. Boulder Committee.*

"I beg, as desired, to report to you, as Convener, that when visiting Loch Skene, Dumfriesshire, last August, I observed some large boulders, about 200 feet above the Loch, in the valley traversed by the Midlaw Burn, between the Mid-Craig and White Coomb hills. These boulders are situated about 1900 feet above the sea-level, and appear generally to belong to the local Silurian rocks. I measured one, and found it to be 30 feet in circumference, 9 feet in height, and 9 feet in breadth. There were others of similar size. The valley in question is dotted with what seem to be moraine heaps, and similar mounds are found damming back the waters of Loch Skene. Scott in 'Marmion' refers to these 'rude barriers.'

"An admirable description of the Geology of this district is given in a paper by Dr John Young in the 'Quarterly Journal of the Geological Society of London,' vol. xx. p. 452 (1864).

"The boulders to which I have referred are evidently not far travelled rocks, but they are interesting as 'perched blocks' occurring at an altitude of 1900 feet. I infer, from the adjacent moraine evidence, that they were transported by a local glacier, which had its *névé* or gathering-ground at the head of the Midlaw valley; which descended to Moffatdale along the present drainage-line, viz., the courses of the Midlaw and Tail Burns; and the northern lateral moraines of which formed barriers to the drainage from the north, resulting in the formation of a sheet of water now known as Loch Skene."

EXTRACTS FROM PAPERS BY THOS. F. JAMIESON (ELLON).

Aberdeenshire and Perthshire.

As it is an object of the Committee to collect information about boulders from all reliable sources, the following notices are taken from papers by Thomas F. Jamieson, Esq., published some years ago in the Proceedings of the London Geological Society :—

(1.) In his paper "On the Pleistocene Deposits of Aberdeenshire" ("Quart. Journ." for 1858, p. 512), Mr Jamieson describes the "*mounds and ridges of coarse ferruginous shingle and gravel*, all water rolled," situated to the north of the town of Aberdeen, near the seashore. "The fields abound with *large boulders*, mostly of syenitic greenstone and other varieties of trap, similar in quality to rock *in situ*, a few miles to the west, near the Menie coastguard station; I found these large boulders of trap, granite, and gneiss, *resting on the top and surface of the gravel ridges*, some of them measuring 6 feet in length, and more or less rounded in form. I traced them also among the low hillocks of blown sand, occurring sometimes singly, sometimes in clusters, and of various sizes up to 11 or 12 feet in length. In a field on the farm of Drums, a gigantic granite boulder occurs, known as 'the grey stone.' I found it to measure 54 feet in circumference, with a height of about 7 feet above the ground. It has no sharp angles, and most of its exterior is rounded. Another immense block, also apparently a transported mass, is seen—78 feet in circumference, and projecting 6 feet out of the ground—a coarse-grained greenstone.

"These ridges consist of highly rolled fragments of rock of all sizes, from coarse gravel up to boulders 2 feet in diameter. On the top of one of these gravel ridges, a little to the north of Drums, I found a boulder of coarse crystalline rock measuring 8 × 5 feet; no sharp angles occur on its surface; a layer of red clay, about 9 inches thick, overlies the gravel at this spot. This boulder rested immediately upon the gravel, but clay encircled its base; another large boulder of greenstone lay beside it.

"These are instances of large transported boulders sitting on the top of abrupt ridges of water-worn shingle."

(2.) In his paper "On the Drift and Rolled Gravel of the North of Scotland" ("Quart. Journ." for 1860, p. 365), Mr Jamieson, referring to "a great ridge of *mica-slate* stretching in an east and west direction, between Loch Tummel and the valley of the Tay," says, that "all along the northern slope of this ridge, from Meal Uaine at one extremity, westward for 10 miles to Hioch Vore at the other, I remarked many boulders of *granite* and *porphyry*, at heights exceeding 2000 feet, the highest being one of granite, at an elevation of 2390 feet.

"Now I examined the greater part of that ridge, crossed it at several points, and walked along its crest for miles, but saw no indication anywhere of this granite or porphyry *in situ*. I think, therefore, they must have been carried to their present position from a considerable distance, and, knowing that such rocks occur in the high mountains situated to the *northward* (as, for instance, Glen Tilt), it is probable, that *there* lies the source from whence they have come.

"It is not at 2000 or even 2400 feet, that we cease to find such transported fragments. In the Braemar district I met with them much higher.

"A remarkable instance of this occurred on the hill of Morven, a few miles to the north of the village of Ballater. The average of four measurements makes the height of it 2953 feet above the sea, the highest value being 3048. It stands many miles apart from any hill of like elevation; in fact, there is none so high within 10 miles, and it greatly surpasses any eminence to the north and east between it and the sea. All the upper part of the mountain, so far as I could ascertain, is composed of one sort of rock, which seems to be a mixture of *greenish hornblende and white felspar.* No *gneiss*, *quartz-rock*, or *granite* came under my notice, although the last-mentioned rock occurs about its base. The late Professor Magillivray had, I find, examined the hill, and pronounced it to be hornblende rock. It was therefore with no small degree of wonder that I remarked several rounded boulders of *granite*, together with some of *quartzose gneiss*, or *laminated quartz*, lying here and there on the western brow of the mountain, and I traced them up to the very summit—one or two, indeed, are built into the cairn that marks the highest point. The largest of these fragments did not exceed 2 feet in diameter.*

"Again, there is a hill close to the village of Braemar, named Cairn-a-Drochet, reaching an elevation of 2700 feet. Seventy yards to the north of the cairn that marks the summit, there sits a *block* of coarse *red granite* 12 feet in length, while many boulders of the same kind are scattered all around. Now the upper part of this hill is chiefly composed of *quartzose gneiss*, intersected with dykes and masses of felspar porphyry, and although *granite* also occurs *in situ* a short way down the hill, yet it is of a different quality from this block, containing a much smaller proportion of quartz, while the felspar is of a paler tint, and, upon the whole, I think it likely that this block and many of the other boulders near it have been derived from the mountains to the north, the granite of which is identical in character. Whilst not meaning to press this too strongly, I would remark that the fragments of quartz, felspar, porphyry, and granite on the flat top of the hill are mingled in such a way as to indicate exposure to some shifting agency, as if they had been washed about together while under water.

"The only other instance of high-lying fragments, apparently transported from a distance, that I shall adduce, relates to the mountain called *Ben Uarn More* (3587 feet). It forms the culminating peak of the great ridge that divides the shires of Aberdeen and Perth, and is composed of *quartz rock;* no other rock occurred, as I clambered up the steep northern slope, but I observed here and there, as I went along, fragments of a peculiar kind of *porphyry* that I had not met with *in situ* lower down. These fragments continued to occur, though sparingly, high up on the shoulder of the mountain, but on the very top I looked some time for them in vain. A cairn on the summit, apparently the work of the Ordnance surveyors, showed nought but quartz, the sharply angular *debris* of which strewed the protruding edges of the strata. Searching about among the quartz *debris*, I did, however, find on the very top of the hill a small lump or two of the same *porphyry;* and other fragments of it occurred as I descended the shoulder of the mountain."

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* The Convener having sent to Mr Jamieson a proof of this part of the Report for his revisal, he returned it, with the following note:—"The Rev. J. G. Michie of Dinnet, accompanied by the Rev. Mr Davidson of Logie-Coldstone, paid a visit to Morven on the 12th October 1874, in order to make a special examination as to the occurrence of these boulders. Mr Michie wrote to me, that they saw some large blocks of *granite* at the base of the mountain, and small boulders of *granite* were likewise found sparingly all over the top of the hill, up to the very summit; but there was a considerable space about half way up, where there seemed to be an absence of these boulders. No granite rock was found *in situ* on Morven itself; the rock, so far as could be seen, being of the nature of hornblende schist."

(3.) In his paper "On the last Changes of Scotland" ("Quart. Journ. of Lond. Geol. Soc." for 1865, p. 165), Mr Jamieson states, that "the detached mountain of Schehallion (Perthshire), 3500 feet high, is marked near the top as well as on its flanks, and this not by ice flowing down the sides of the hill itself, but by ice pressing over it from the north. On the top of another isolated hill, Morven, about 3000 feet high, situated a few miles to the north of Ballater (Aberdeenshire), I found *granite boulders* unlike the rock of the hill, and apparently derived from mountains to the west.

"Again, on the highest watersheds of the Ochils (a range of trap-hills stretching from Stirling towards Perth), at altitudes of about 2000 feet, I found pieces of *mica schist* full of garnets, which seem to have come from the Grampian Hills to the north-west, showing that the transporting agent had overflowed even the highest parts of the Ochil ridge.

"On the Perthshire hills, between Blair-Athole and Dunkeld, I found ice-worn surfaces of rock on the tops of hills, at elevations of 2200 feet, as if caused by ice pressing over them from the north-west, and *transported boulders* at even greater heights."

Referring to boulders in brick-clays, Mr Jamieson (p. 178) mentions that in "the Paisley brick-clay, which abounds in sea-shells (all of them Arctic), boulders of from 1 to 3 feet in length are not uncommon. I saw one 6 feet in length. Many of them show the glacial *striæ.* These boulders occur imbedded here and there at various depths. It is common to find a crust of *Balani* attached to one of these boulders. It has generally been supposed that the *Balani* are confined to the upper surface and sides of the stone, as if they had grown upon it after it had been dropped into its present position. I satisfied myself, however, that this is not always the case, for I found that *Balani* do occasionally occur all over the lowermost side. For example, I observed one heavy stone, measuring 32 × 18 × 14 inches, imbedded in the clay about 15 feet from the surface. This boulder had not been moved out of its original position, and there were remains of *Balani* on various parts of the surface. I dug round it, and heaved it out of its bed, and found that the whole under side of it was covered with a close, thick crust of entire *Balani*, the points of which were sticking downwards into the soft clay beneath, showing clearly that they must have grown upon the stone, before it was dropped into its muddy bed. Other instances of the same kind were observed by me. I conclude, therefore, with regard to some of these boulders at least, that *Balani* grew on them before they came to be lodged in the clay (probably when they lay on some shore) and that afterwards they had got encrusted with ice, and being floated off, had dropped to the bottom when the ice about them melted."

Mr Jamieson, in a footnote, adds—"I believe the species of *Balanus* on the under side of the boulder above-mentioned was *B. balanoides* of Darwin's monograph, which is a species that lives only between tide-marks. If this is correct, then, it could scarcely have grown on stones lying in water so deep as is indicated by the shells in this clay, and its presence could be explained only by some such theory as I have suggested. It would be an interesting fact should the *Balanus* on the upper surface prove to be of a deep-water species, and those on the lower of a tidal one."

REMARKS BY MR MILNE HOME.

After presenting the Seventh Boulder Report, and giving a verbal account of its principal contents, Mr Milne Home, with the permission of the Council, read the following remarks, bearing on the objects of the Committee:—

First.—In reference to further explorations, I entirely concur in the opinion of Professor Heddle, given in the Report, that the boulders most deserving of being sought for and studied are those perched at great heights, and especially on the ridges and tops of hills. (An example of one of these "perched blocks," as described in last year's Report, was shown by a diagram on the walls.)

It is quite certain that boulders in such positions had been put there and left there by the transporting agent (whatever that was) which brought them; and therefore whatever inferences their position indicates, these inferences may be relied on as correct.

Boulders in valleys, or at the foot of a hill, on the other hand, may by mere atmospheric action have lost their original positions, by having rolled to a lower level; in which case, they can afford no true data for inference.

They may, however, when found in valleys, have come there by local glaciers; and such cases are mentioned in previous Reports of the Committee. But where boulders are on hill ridges or hill tops, at heights exceeding 2000 or 3000 feet above the sea (and cases of that kind have been mentioned in our Reports), in districts where there are no hills much exceeding that height, local glaciers as transporting agents are inconceivable; and equally so seems to me the agency of a general ice-sheet moving over the country; for such a raft would have the effect, not of depositing boulders on hill tops, but of sweeping everything off them.

Second.—The discovery by Professor Heddle of one or more streams or *trainées* of boulders, in the Highlands, is very important by affording additional data towards the solution of the problem, what was the transporting agent? The late Hugh Miller speaks of having seen boulders in a continuous line at two places in Mid-Lothian ("Edinburgh and its Neighbourhood," p. 35); but the best examples, which I can specify, of boulders in continuous streams, occur in the United States. They have been described by Hitchcock, Henry Rodgers, and Dana, all well-known American geologists. One of these places was visited by Sir Charles Lyell, who, in a lecture at the Royal Institution, London, in the year 1855, gave an interesting account of it.

This lecture I have found in a volume of pamphlets in our library. It contains a diagram, which I have caused to be copied on a scale large enough to be seen on the walls, thinking it might be of service in suggesting further explorations in our own country.

(The diagram was here shown and described.)

The explanation of these Massachusetts boulder streams, implies the submergence of the country to the extent of about 2000 feet, under an arctic sea, capable of allowing ice to be formed. Now it is generally agreed, that Scotland, England, and Ireland was, during the Glacial period, submerged, so that most of our hills were covered; and judging by the types of molluscs, and skeletons of seals (of a species existing only in an arctic sea) found in our clay beds, the submerging ocean must have been of an arctic character.*

With reference, therefore, to such *trainées* of boulders, as have been found by Professor Heddle, among the Highland hills, the same explanation is, to say the least, admissible.

Third.—But there are other districts covered with boulders to which this explanation is not applicable. I refer to the Western Islands and the Hebrides (Islay, Tiree, Barra, Uist, and Harris), all of which have numerous boulders on hill slopes facing the Atlantic, and which, judging by the peculiar position and attitude of many of them, clearly show that they have come from a westerly or north-westerly direction. On these islands, with no ranges of hills on them of the necessary height, local glaciers are out of the question. On the north-west coast of Argyleshire, there are, in like manner, boulders in positions which convinced the late Robert Chambers, the late Dr Bryce, the late Professor Nicol, and Mr Jameson of Ellon, all of whom personally examined them, that they also had come across the sea, and not from any inland district.

But where in a direction west or north-west, is there any land from which these boulders could have come, and how could they have traversed the wide Atlantic? Though there are probably entire hills of granite and gneiss in Labrador and Greenland, it is hardly conceivable that any ice-bergs or ice-floes obtaining boulders there, could reach our shores to discharge their cargoes upon them, even though there had then been no Gulph-Stream to intercept and melt them.

Is no other hypothesis possible?

(1.) There now exists, about 190 miles to the west of the Hebrides, a range of submarine granite hills, whose peak, called in our charts "*Rockall*," stands above the sea-level to the height of 80 feet; and within about 2 miles from it, there are two rocks, apparently parts of the same range. That "Rockall" is granite was attested by the late Captain Basil Hall,* and subsequently by the surveying officer of H.M.S. "Porcupine"; the latter stating in his memoir to the Admiralty, that he had sent specimens of the rock to several museums in Ireland. The soundings show, that the 100 fathom line extends N.N.E. about 20 miles, and S.S.W. 32 miles, whilst in a transverse direction, the shorter axis is only 12 miles, so that this granitic range is approximately parallel to the axis of the Hebrides.

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* See an interesting article by Professor Turner of Edinburgh University, on these fossil seals, in "Journal of Anatomy," vol. iv. p. 270.

Of course these rocks would not, *at their present level*, have supplied the boulders now in the Hebrides and coasts of Argyle. But there is a very general belief among those who have studied the subject, that at or about the period when these boulders came, land did exist in the North Atlantic, which is now submerged.

The late Edward Forbes, in a remarkable memoir published in the year 1844,† was the first to express this opinion, founded on a consideration of the flora and fauna of Scotland and Ireland. He says, "There could not always have been such a separating abyss between Northern Europe and Boreal America as now divides them. The sea through a great part, must have been a shallow sea; and somewhere, probably to the far north, there must have been either a connection or such a proximity of land, as would account for the transmission of a non-migratory terrestrial and a litoral marine fauna." In another part of his memoir, he says, "Although I have made ice-bergs and ice-floes the chief agents in the importation of flora southward, I cannot but think, that so complete a transmission of that flora as we find on the Scottish mountains, was aided, perhaps mainly, by land to the north, *now submerged.*"

(2.) This opinion, since it was expressed, has received support from other considerations. Thus in 1853, the late Sir Charles Lyell expressed his belief, founded on observations by a Danish captain, that the west coast of Greenland was subsiding. More extended observations have since been made by two American men of science, Dr Kane‡ in 1855, and Dr Hayes in 1860, which show clearly that whilst the north part of Greenland had long been rising, the south part of the continent was and had been subsiding. They inferred the position of the centre of oscillation to be between latitudes 76° and 77°. The elevation of the *northern* portion, they thought, was indicated by old sea terraces, forty-one in number, reaching up to 480 feet above the sea, and at a distance of about 120 miles from the axis of oscillation. To the *south* of this axis, no such terraces are visible, but on the other hand there are remains of human habitation, and other appearances indicating submergence. Dr Kane mentions that subsidence had also been observed on the eastern coast of South Greenland. The distance to what is now the south cape of Greenland, from the axis of movement, is about 1000 miles; and if it be assumed that the amount of subsidence on the north side of the axis is the same as that of elevation on the south side, the subsidence at the south cape would be about 3200 feet. But this subsidence would most probably not be confined to Greenland. It might have extended into what is now the bed of the North Atlantic, verifying therefore Forbes's remarkable inference, founded on physiological data, " that land had at one time existed there, now submerged."

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* Fragments of Voyages.

† "Memoirs of the Geological Survey of Great Britain for 1844," vol. i. p. 383.

‡ Kane's "Arctic Explorations," London, 1875. Dr Hayes's "Open Polar Sea," London, 1867.

(3.) On the east side of the North Atlantic, there are also traces of subsidence.

Thus Jukes says, that " Around all the shores of Ireland, there is found evidence of a comparatively recent depression of the land, in the occurrence of undisturbed peat bogs beneath the sand of the sea, stretching below the level of the lowest spring tides. The stumps and roots of trees in the position of growth are found in this peat, clearly showing that it grew on dry land, and is now beneath the sea in consequence of depression" ("Manual of Geology," p. 686).

O'Flaherty, in reference to a traditionary belief existing in 1630,* says that " Lough Lurgan is an inlet of the sea between Tuam and West Connaught, at the mouth of the Galway, stretching into the land, which was formerly dry land, *until the Western Ocean broke over it.* The remains of the barrier, are the three Isles of Aran. This traditional name (Lough Lurgan) is still used for Galway Bay; and margining the bay, below low-water mark of spring tides, there are numerous bogs with oak corkers *in situ* at their base, in places over 12 feet deep."

Mr Kinahan, in his " Geology of Ireland," records that " the Rev. W. Kilbride, vicar of Aran, has discovered in the principal island, human habitations and other structures below low water of spring tides" ("Journal of the Royal Geological Society of Ireland for 1880," vol. v. p. 180).

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* " Ogygia," seu " Rerum Hibernicarum Chronologia," London, 1685.

(4.) Reference has been made to "*Rockall,*" which at present consists of only *one* rocky peak. But a chart exists dated in 1634,* which represents the place as consisting of two islets, a larger and a smaller, but the smaller is now exposed to view only at half tide,† suggesting subsidence.

(5.) Another discovery recently made, is the finding in several parts of the North Atlantic, molluscs which betoken *littoral* conditions. Thus on the Porcupine Bank—a shoal situated about 120 miles west of Galway (Ireland), a specimen of "*Litorina litorea*" was dredged up, with regard to which Professor King of Queen's College, Ireland, asks, "How has this shell, which lives between ordinary tide marks, got into 80 or 90 fathoms of water, and at a distance of 120 miles from the shore?"†

A similar case occurs in a part of the North Atlantic, about halfway between the south end of Greenland and Rockall, where a number of *star-fish* were brought up by the sounding line from the sea bed at a depth of 748 fathoms. Dr Wallich, in the "Bull Dog" surveying ship, employed in 1860 to make these soundings, drew out an exceedingly interesting memoir ‡ (published by the Admiralty), in which he gives his "reasons for believing that although originally a shallow-water species, these star-fishes had gradually, and through a long series of generations, accommodated themselves to the abnormal conditions incident on the subsidence of the sea bed" ("Memoir," p. 141).

Dr Wallich further observes, that "no proof of subsidence could be more complete, than the detection of a colony of acclimatised star-fishes belonging to a species typical of the Boreal province, well known to range from the confines of the Arctic circle to our own shores, and shown to have accommodated themselves to a depth of 200 fathoms without variation; whilst the fact of subsidence being general through the whole area, is rendered probable by the discovery of *sessile annelids,* also belonging to known shallow-water species, at a depth of 620 fathoms, half way between Iceland and the Faroe Islands" (p. 152).

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* The chart alluded to is a French navigating chart, of which a copy is given in the 5th volume of the Royal Irish Geological Society.

† "Report of Soundings by H.M.S. 'Porcupine' in 1862."

‡ "North Atlantic Sea-bed," by G. C. Wallich, F.L.S. and F.G.S., naturalist to expedition under Sir F. L. M'Lintock, "to survey the proposed North Atlantic route for a telegraphic wire between Great Britain and America."

"The occurrence of a shallow-water *Serpula* at such a depth is important, from the evidence it yields of the subsidence having been gradual, and not merely the result of local and temporary submarine volcanic action; for whilst creatures having powers of locomotion might have evaded the consequences of sudden subsidence by migration to shallow water, the *sessile annelids* must inevitably have been destroyed. The detection of shallow-water species on isolated submerged areas of sea bed, may enable us to determine, whether such areas have been nearer the surface at some anterior period, and may thus afford a glance, otherwise unattainable, at the lost land-marks of a byegone geological epoch" (p. 151).

One other circumstance, bearing in the same direction, though I confess that I do not attach much value to it, may be mentioned, viz., the existence of old French and Norwegian charts, which represent an island not far from the place where the *star-fishes* were dredged up.

These circumstances induced Dr Wallich to express an opinion somewhat similar to that which Forbes had, on separate grounds, formed, that "an ancient barrier had stretched across from East Greenland towards the shores of Northern Europe. On reference to the map it will be seen, that a vast area of sea bed to the south of Iceland, extending to the 30th degree of west longitude on the one hand, and to the Faroe Islands and Hebrides on the other, gradually diminishes in depth as it advances northwards; in all probability constituting the boundary of an archipelago rather than a continuous continent, across which the various species of animals and plants made their way southwards. When that archipelago existed, the Hebrides and Faroe Islands were probably united, whilst Rockall formed a large but distinct island; and another still larger island rose up out of the sea between the 57th and 60th degrees of latitude, and about the 30th degree of west longitude. On the northern flank of this island, the star-fish sounding was taken" ("North Atlantic Sea-bed," p. 150).

If these speculations are well founded, there need be little difficulty in understanding from what quarter the Hebrides and Argyleshire boulders have come; whilst the fact, if it be verified, that they did come across the Atlantic from the west, is an additional link in the circumstantial chain which supports a theory advocated by the distinguished naturalists to whom I have referred.

The inquiry, however, being of considerable geological interest, I should wish that the positions of the boulders on the west coast of Scotland did not rest on my personal observation (as at present they chiefly do), but that they would engage the attention of others, and who, I hope, will report the result of their enquiries to the Boulder Committee.

2. On the Compression of Gases by High Pressures. By Professor Tait.

3. Determination of Longitude without a Chronometer. By Dr Menzies. Communicated by Professor Tait.

4. The Electric Discharge through Colza Oil. By A. Macfarlane, M.A., D.Sc., F.R.S.E.

(*Abstract.*)

The dielectric strength of colza oil (specific gravity ·91) was found to be 2·7, that of air at the ordinary pressure being unity- The rest of the paper is taken up with a description of the phenomena accompanying under different conditions the spark discharge through the oil.

5. On Quaternion Integration. By Professor Tait.

The Chairman closed the session with the following remarks:—

I have now, in a very few words, to close this session, and in so doing I beg to remind you that it is the ninety-ninth session of the Royal Society of Edinburgh. This Society, which was originally an offshoot of the University of Edinburgh, was first started, on the suggestion of Principal Robertson, towards the close of 1782. So that in the latter part of next year you will be able to announce your hundredth birthday. The Society came into existence just one year after its late distinguished President, Sir David Brewster, who was born in December 1781. While individuals pass away, age brings no decrepitude, but rather the reverse, to universities and scientific bodies. For, owing to the growth of population and national wealth around them, there is a constantly increasing class of persons demanding the higher branches of education, and with leisure for scientific pursuits. It might, however, be the case that a Society like this, while flourishing in numbers, might fall into the condition of the army of Xerxes, of which it was said that there were πολλοὶ μὲν στρατίωται, παῦροι δὲ ἄνδρες—"numerous troops, but few real men among them." This, however, can by no means be now said of the Royal Society of Edinburgh. The past session has exhibited an amount of vitality and productive energy which does great credit to the Fellows, and, I may add, to the Secretaries, to whose assiduity and tact the flourishing condition of the Society is greatly due. I believe that few previous sessions on our records show a better tale of work done than the session which we are now concluding. During its course no less than seventy-three papers have been furnished, upon the most varied topics, almost entirely by Fellows or Honorary Fellows of the Society. The series was opened by the noble President with a literary address, recalling to notice some once famous, but now nearly forgotten, works; and then followed seventy-two papers, of which 17 are Mathematical; 20 Physical; 12 on departments of Natural History; 10 Chemical; 3 on Astronomy; 1 Mineralogy; 1 Geology; 1 Anatomy; 1 Meterology; 6 Logic, &c. To appreciate the matter and contents of all these various papers would require the many-sided intellect and universal accomplishment of a Humboldt. And even Alexander von Humboldt, could he have come to life again and attended our meetings, would have heard things not dreamed of in his philosophy—so progressive is science. I venture to offer no further word beyond congratulating you on the amount of work done during the session. In a week or two we shall be all dispersed—some to foreign lands, some in the country, or among the mountains, or by the sea. I doubt not that the Fellows of this Society, wherever they are, will find the truth of the often-quoted sentence: "Hæc studia delectant domi, non impediunt foris, pernoctant nobiscum, peregrinantur, rusticantur." And I trust that your hundredth session may reap the fruit of new ideas which shall have uggested themselves during the ensuing recess.

On the Classification of Statistics and its Results. By Patrick Geddes, F.R.S.E., Lecturer on Zoology in the School of Medicine, Edinburgh, and Demonstrator of Botany in the University.

(Sections 1–16 read on 21st March ; 17–26 on 4th April ; 27–31 on 2d May 1881.)

§ 1. Every one may readily notice that the collection of statistical information goes on around us to a vast and constantly increasing extent; not simply in the periodic census, but in the daily labours of the Registrar-General's Department, of the Board of Trade, and the like. Such functions are carried on in every civilised country by many special statistical bureaux; a statistical society exists in almost every great intellectual centre, and an International Statistical Congress, which has proposed to itself the vast object of accumulating, co-ordinating, and comparing the whole body of national statistics, has met periodically since 1853.

Though no one will probably question the desirability and usefulness of such a task, it may be well to point out that in the words of a veteran statistician *—"By this means light will be thrown on every branch of statistical science. All social phenomena of every kind may be investigated by comparisons of the different causes from which they arise, under different conditions, and in countries presenting wide spheres of observation and opposing influences at work. Knowledge will thus be increased, laws of social life eliminated, true scientific inquiries promoted, the work of government simplified, and the progress and prosperity of nations fixed upon sure bases of observation and reason, instead of dangerous experiments or doubtful theories."

Again, regarding the importance of uniformity (*i.e.*, of orderly classification) in all statistical publications, the same authority † has insisted that "What was wanted, above all things, was uniformity.

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* S. Brown, F.S.S., "Report on the Eighth International Statistical Congress, St Petersburg, 1872"; Journ. Statist. Soc. Lond., vol. xxxv., Dec. 1872, p. 457.

† Quoted by Mouat, "Prelim. Report of Ninth International Statistical Congress, held at Buda-Pesth, 1876"; Journ. Statist. Soc. Lond., vol. xxxix., Dec. 1876, p. 645.

Hundreds, we might say thousands, of volumes—collected and printed at great expense by the different Governments, by societies, or by individuals, were rendered almost useless, in an international point of view, for want of some uniform method of classifying and showing the results. It was impossible to make comparisons, and so to educe the laws of probability of occurrence of large classes of events in social or political economy. Yet, without the discovery of these laws, the social, moral, and intellectual condition of a people cannot with any certainty be traced."

§ 2. It thus becomes necessary to examine and compare the modes of classificaiton of statistics actually in use in the statistical annuals of different countries. This has been done by M. Deloche,* chief of the Statistical Department of the Ministry of Agriculture and Commerce, and also by Dr Mouat, Foreign Secretary of the Statistical Society of London †; and it will be useful to borrow a few examples, placing the condensed headings in parallel columns. (See opposite page.)

§ 3. After pointing out the utter discord which exists among these systems, and the necessity of some fundamental scientific idea to introduce uniformity, Deloche goes on to propose a classification, based upon the idea of the human organisation. Of this classification a detailed account is given by Mouat, from whom the following summary also is borrowed:—

I. *Double Synthesis of the Territory and its Population.*

1. Territory (topography, geology, hydrography, meteorology).
2. Census and movement of population.

II. *Facts relating to the Exercise of the Moral Faculties.*

1. Religion.
2. Civil and criminal justice.
3. Prisons and penitentiary establishments.
4. Public aid.
5. Benefit societies.

(*Continued on page* 298.)

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* Quoted by Mouat, "Report on the Fourth Session of the Permanent Commission of the International Statistical Congress, held in Paris, 1878"; Journ. Statist. Soc. Lond., xlii., p. 12.

† *Ibid.*

BELGIUM.	AUSTRIA.	HUNGARY.	UNITED KINGDOM.	COLONIAL AND OTHER POSSESSIONS.	BRITISH INDIA.
I. *Territory and Population.* 1. Territory. 2. Population. II. *Political, Moral, and Intellectual State.* 1. General Elections. 2. Provincial Elections. 3. Communal Elections. 4. Provincial Administration. 5. Criminal Administration. 6. Primary Instruction. 7. Higher Education. 8. Letters and the Fine Arts. 9. Worship. 10. Medicine. 11. Benevolent Institutions. 12. Civil Justice. 13. Criminal Justice. 14. Civil Guards. 15. Militia. 16. Army. III. *Agriculture, Industry, Commerce.* 1. Agriculture. 2. Industry. 3. Commerce. 4. Banks, &c., Mints. 5. Communication. 6. Post and Telegraphs.	1. Superficies, population, dwelling-places, movement of population. 2. Rural economy, cattle, market prices, extractive industry. 3. Manufacturing industry, commerce. 4. Railways, roads, river and sea navigation, post office, telegraphs. 5. Clergy, education, press. 6. Civil and criminal justice, &c. 7. State administration, public debt, &c., communal administration. 8. Joint-stock Cos. banks, sale of property and mortgages. 9. Savings banks. 10. Hygienic and charitable institutions, fires. 11. Army and navy.	1. Movement of the population. 2. Rural economy. 3. Mines. 4. Movement of commerce, market prices. 5. Modes of communication. 6. Fires. 7. Public health. 8. Justice. 9. Worship and public instruction. 10. Government.	1–12. Public and local revenue and expenditure, national debt, income-tax, customs, tariffs, &c. 13–14. Imports and exports. 15–21. Imports. 22–29. Exports. 30–31. Bullion. 32–35. Transhipments. 36–42. Shipping. 43–44. Excise. 45–46. Prices and sale of corn. 47. Acreage under crops and live stock. 48. Coinage. 49. Post office savings banks. 50. Savings banks under trustees. 51–57. Bank of England. 58–61. Post-office. 62. Population. 63. Births, marriages, deaths. 64–65. Education. 66–69. Paupers. 70. Crime. 71. Emigrants. 72. Railways. 73. Mines.	1. Area and population. 2. Revenue. 3. Expenditure. 4. Public debt. 5. Shipping. 6. Imports. 7. Exports. 8. Banks. 9. Railways. 10. Agriculture. 11. Births, deaths, and marriages. *Australian Colonies.* 12. Meteorology. 13. Import duties. 14. Export duties.	1–19. Area and population. 20–37. Revenue and Expenditure, debts and obligations, provincial and local finance, municipalities. 38–43. Shipping. 44–45. Imports. 46–49. Exports. 54–56. Government stores. 57–60. Gold and silver. 61–62. Customs Tariffs. 63. Coinage. 64–68. Paper currency. 69. Emigrants. 70–79. Guaranteed and State railways. 80–83. Public works. 84. Telegraphs. 85–92. Post-offices. 93–98. Army. 99–100. Education. 101. Publications. 102. Vaccination. 103–104. Wild beasts.

III. *Facts relating to the Exercise of the Intellectual Faculties.*

1. The three degrees of public instruction.
2. Literary and scientific productions, printing, books, libraries, museums ; newspapers and reviews.
3. The fine arts.

IV. *Facts relating to the Application of the Physical Faculties and of the Intellectual Faculties to Natural Objects.*

1. Agriculture.
2. Lands built upon and land without buildings.
3. Extractive and manufacturing industry. Fisheries.
4. Professions and salaries.
5. Means of communication.
6. Commerce and navigation.
7. Public works, public health, and the food supply of towns.
8. The circulation of men, of things, of valuables, and of thought. Post offices and telegraphs.
9. Credit institutions (except State banks).
10. Accidents and assurances.

V. *Facts common to the three above-mentioned orders of faculties.*

1. Political rule, its organs and assemblies.
2. General administration.
3. Administration and assemblies of provinces, departments, districts, communes, and minor subdivisions.
4. Army.
5. Navy.

VI.

1. The finances of the State.
2. The finances of provinces or departments.
3. Finances of communes or inferior districts. Town dues and articles consumed.
4. State banks—*les caisses de depôts*—mints.

VII. *Colonies or Extra Continental Possessions.*

Dr Mouat, while admitting this scheme to be "undoubtedly the best attempt yet made to reduce to order and precision that which is at present deficient in both these qualifications," yet holds it to be impracticable, since it is doubtful whether there could be any approach to general consent, either as to the divisions themselves or to the subdivisions placed in each. M. Deloche's fifth division seems to him to be fatal to the plan, and the reader will readily notice many other objections.

§ 4. He then goes on to suggest a temporary and provisional classification, which is summarised as follows:—

"I. *Territory and Population.*

"All geographical and demographical statistics, including areas, soils, climates, possessions, and territorial arrangements, movements and divisions of the population, and the purely social arrangements, such as trades, professions, &c., everything contained in the registrar-general's returns, and what is beginning to be known as sociology generally.

"II. *Revenue and Commerce.*

"All the sources of the collection, production, and distribution of wealth, the statistics of the precious and other metals, all facts relating to the use and abuse of money, exchange operations, all manufactures and industries, and commerce in its widest sense, including means of transport, navigation, &c., &c.

"III. *Laws and Government.*

"All relating to legislation and policy of nations, which would include the making and breaking of laws, the constitution of imperial and local governing bodies, armies, navies, police forces, and the like; education and religion, and all facts tending to show the state of civilisation of each nation as distinguished from other nations.

"IV. *Miscellaneous* (arranged alphabetically).

Such an arrangement is, of course, as Dr Mouat indeed admits, the despairing abandonment of all pretence of scientific arrangement; and it is curious to notice that this—the latest development of statistical classification,—is closely analogous, save for the *omnium gatherum* with which it concludes, to that earliest classification with which botanists commenced their labours, that of the vegetable world into herbs, shrubs, and trees. Under these circumstances the interference of the naturalist may be less impertinent than might at first sight seem probable.

§ 5. Before attempting classification, it is necessary to come to some definite agreement as to the nature of statistics; and after laying aside the popular belief that it is an inexpressibly dreary accumulation of numbers by which anything whatever may be proved, we find that at least two hundred non-coincident definitions have been given by statisticians. Many of these assert statistics to be a *science*, many again regard it as a *method;* while some, including the most recent foreign authorities, claim that it is at once both. But the sciences (using even the widest classification, that of Herbert Spencer) are logic, mathematics, physics, chemistry, astronomy, geology, biology, psychology, sociology, and ethics; the methods of science (according to Bain) are simply observation and definition (classification), induction and deduction. We do not find statistics in either category. Some statisticians, however, hold the sound view that statistics is simply a quantitative record of the observed facts or relations in any branch of science,* and I have ventured to condense and define this view into a diagram, as follows:—

Record of Facts (*at given time*).

<table>
<tr><td>Qualitative.</td><td colspan="4">Quantitative.</td></tr>
<tr><td>Verbal.</td><td>Numerical.</td><td>Linear.</td><td>Plane.</td><td>Solid.</td></tr>
<tr><td></td><td></td><td colspan="3">Graphic</td></tr>
<tr><td>Statements.</td><td colspan="4">Statistics.</td></tr>
</table>

§ 6. If this definition be correct, we obtain history by superposing or combining successive records, and this view is identical with that

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[*] For a valuable discussion of recent opinion as to the nature of statistics, in which this latter view is substantially maintained, see Hooper, "On the Method of Statistical Analysis"; Journ. Statist. Soc. Lond., vol. xliv., March 1881.

expressed in the famous aphorism of Schlözer, one of the earliest writers on the subject—"Statistics is history in repose, history is statistics in movement." Applied to sociology, it practically agrees too, with the division of the subject into social statics and social dynamics established by Comte.

§ 7. The field of history might at first sight seem co-extensive with that of statistics, and both might seem to extend to all the sciences; but since logic involves no idea of quantity, and since mathematical, physical, and chemical conditions and properties are constant, the scope of statistics and history becomes restrained, as shown in the following diagram:—

- Sciences
  - Statistical
    - Historical .
      - Ethics.
      - Sociology.
      - Psychology.
      - Biology.
      - Geology.
      - Astronomy.
    - Chemistry.
    - Physics.
    - Mathematics.
  - Logic.

It is thus clear that statistics and history are, within the above limits, the common property of the sciences, and that the current use of these words, which restricts them to social phenomena, is simply one of colloquial convenience, while their use in the sense of distinct sciences or of distinct scientific methods is entirely erroneous.*

§ 8. Statistics being thus defined, the need for collection and classification being granted, and the unsatisfactoriness of existing and proposed schemes of classification being shown, we must now proceed to consider the desiderata of a system of classification. Our classification must be natural, not artificial; must be capable of complete specialisation, so as to include the minutest details, and capable, too, of the widest generalisation; it must be universal in application, and it must be, as far as possible, simple of understanding, and convenient in use. But how shall we obtain such a classification? What phenomena in the whole field of human knowledge have as yet been classified in this way? A moment's consideration will show that it is biological science which alone answers the question satisfactorily. None of the preliminary sciences is wanting in order or definiteness, but to biology above all is presented the problem of an innumerable multitude of actual phenomena demanding arrangement. Take an instance from zoology. Birds and reptiles, fishes and worms, are groups which the common sense of probably every rational human being enables him to form with considerable approach to correctness; yet at this point the task of the zoologist is only beginning. He has to work in two directions, to specialise until every member of these groups is known in the greatest detail, and also to generalise these groups into larger and larger ones. The two lines of research may be represented thus:—

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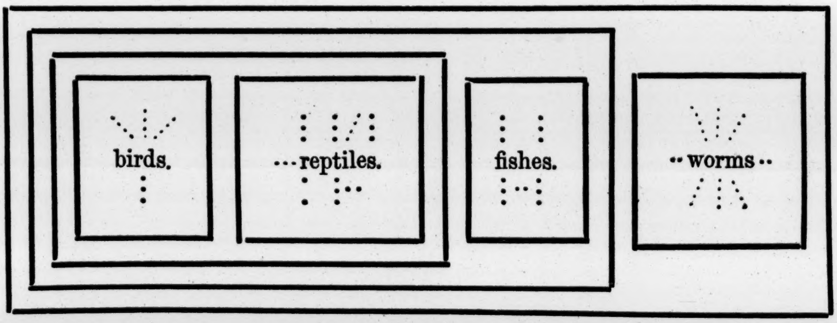
* The preceding general conceptions may be traced into interesting detail. The application of the above diagrammatic definition of statistics to all the sciences clearly illustrates the continual progress which goes on in each from mere qualitative to quantitative knowledge, and the increase of definiteness which qualitative knowledge is always tending to assume. For instance, the name of a chemical compound, say sulphate of iron, expresses only a qualitative relation, its ordinary chemical formula $FeSO_4$ reaches the numerical state, its graphic and glyptic formulæ are respectively the plane and solid representation of the same *statistic*, as we may conveniently term any such relation of quantity. So, too, the astronomer has his star-maps and orrery, the geologist his maps and models, the biologist his figures and diagrams, while the sociologist so often requires similar aid that the French Government has recently established a *Bureau de Statistique graphique*. So by piling up successive graphic representations of statistical observations, a solid historical



letting the dots represent the details of the various groups, and the large rectangles the successive generalisations which combine

model might often be constructed. A geologist, for instance, by piling map upon map of a given island at successive times (the margin being of course removed) would thus construct a solid model which would clearly exhibit the changes throughout the whole period. Where the area was increasing per unit time, the solid would widen upwards and overhang its base; where decreasing it would narrow, and thus even the minutest local increase or decrease would be represented with extreme vividness.

these into larger and larger alliances. Such a method of classification is obviously, therefore, that of which we are in search. It accepts our ordinary conceptions as far as possible, and systematises them; it is in real accordance with the order of nature, it pushes specialisation and generalisation to the uttermost limits of possibility, it is universal in application, and, as far as possible, simple of understanding and convenient in use.

§ 9. Using, therefore, the ordinary method of the classificatory sciences, let us take a concrete case—let us examine some actual statistics. For this purpose nothing is better than the useful little *Annuaire*, published by the *Bureau des Longitudes*.* Some of its principal contents are as follows:—Calendar, times of eclipses, sunrise and sunset, tides, &c.; tables of weights, measures, and money; heights of mountains, depths of rivers; superficies and population of European and other countries, special statistics of France, her colonies and Paris, laws of mortality, &c. Then come "*Tables diverses*" in great number, of which the few following instances will suffice:—Magnetic inclination, chemical elements, specific gravities of elements, rocks, gems, thermo-chemistry, velocity of sound, indices of refraction.

At first there is no difficulty. We simply separate out in order the statistics of each of the preliminary sciences, physical, chemical, astronomical, geological (including geographical, meteorological, &c.), and leave these to their special cultivators. It will be noticed that even this simple step disposes of a not inconsiderable part of the actual statistics of various countries (*e.g.*, see *Austria, Colonies*, &c., p. 297). Social statistics now alone remain; how are they to be classified in accordance with our canons?

§ 10. Let us first inquire what is the fundamental scientific idea of a society. Some statists and economists answer exchange, others division of labour, others find it in history, others in the rights of man or the like. This diversity of opinion makes it unnecessary to criticise each in detail, and we are thrown back upon our own resources—our knowledge of the preliminary sciences. Just as the biologist is accustomed to classify man along with inferior organisms, and to trace the fundamental resemblances in structure and function which his organisation presents to theirs, so he may reasonably inquire wherein human society resembles the societies formed by the lower animals, the more so as no one disputes that these fall strictly within his province.* As the term society indeed assumes, some general truths must be common to societies of *Formica*, *Apis*, *Castor*, and *Homo* alike—to ant-hill, bee-hive, beaver-dam, and city, and this must therefore underlie our classification of social facts.

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* Paris: Gauthier-Villars.

§ 11. First, then, a society obviously exists within certain limits of time and space. Secondly, it consists of a number of living organisms. Thirdly, these modify surrounding nature, primarily by seizing part of its matter and energy. Fourthly, they apply this matter and energy to the maintenance of their life, *i.e.*, the support of their physiological functions.

It is here clearly to be understood that no attempt is made completely to define a society. A society may be much more than all this, in which case more general truths are discoverable, but in any case these four generalisations are obviously true, neither hypothesis nor metaphysical principle being involved. These will therefore henceforth be termed sociological axioms. What aid can they afford us?

§ 12. They enable us to classify out the facts relating to each and every society as follows :†—

(A.) Those relating to the limits of (1) time and (2) space occupied by the given society.

(B.) Those relating to the matter and energy utilised by the society from surrounding nature.

(C.) Those relating to the organisms composing the society.

(D.) Those relating to the application of the utilised matter and energy by the given organisms.

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* "The Biological sciences are those which deal with the phenomena manifested by living matter ; and though it is customary and convenient to group apart such of these phenomena as are termed mental, and such of them as are exhibited by men in society under the heads of Psychology and Sociology, yet it must be allowed that no natural boundary separates the subject matter of the latter sciences from that of Biology. Psychology is inseparably linked with Physiology ; and the phases of social life exhibited by animals other than man, which sometimes curiously foreshadow human policy, fall strictly within the province of the biologist."—Huxley, "Anatomy of Invertebrated Animals," London, 1877, p. 1, Introduction.

† For better agreement with the order of the sciences (see p. 301), it is convenient to transpose the classes of facts derived from the second and third axioms.

§ 13. We may now proceed briefly to discuss these in order, not tracing them into more detail than is essential for clearness.

A. (1.) Of the extreme limits of time either or both may or may not be known, but the time at which our record of facts is taken can be, and usually is, stated definitely at the outset as a date.

(2.) Limits of space. Leaving all purely physiographical questions to the preliminary science of geology, the essentially social space relations may be arranged as follows:—

A. *Territory of given society.*

- I. Quantity at given time.
    - 1. Persistent since last unit time.
    - 2. Added since last unit time.
        - (*a*) By geologic agency (upheaval, deposition, &c.).
        - (*b*) By social agency (discovery, conquest, reclamation, purchase, &c.).
- II. Quality at given time.
    - 1. Unused.
    - 2. Used.
        - (*a*) Unspecialised (for such and such functions).
        - (*b*) Specialised (for such and such functions).
- III. Decrease since last unit time.
    - 1. By geologic agency.
    - 2. By social agency.

§ 14. Let us now pass to the body of facts which our third axiom enables us to co-ordinate—those (B) relating to the matter and energy utilised by the given society.

The primary sources of energy in nature, so far as we at present know, are four—first, the primitive chemical affinity of the uncombined elements; secondly, the internal heat of the earth; thirdly, the rotation of the earth; fourthly, the sun. Of these the last is, of course, by far the most important; and its energy exists either active in sunshine, moving air, or water, or latent in the earth's crust, or in the organisms surrounding or composing society. The energy of the earth's rotation has been used to some small extent in tide-mills; that of the earth's internal heat, as manifested in hot springs, volcanoes, &c., of course still less; while the first source, that of primitive chemical affinity, is scarcely used at all, since the elements (with the partial exception of sulphur) are desired for the sake of other properties than their capacity of yielding energy.

The next portion of the same table, that intended for the arrangement of our knowledge of the substances used, not for the production of energy, but for the sake of their physical, chemical, physiological, or other properties, may most simply be divided according as the substances are animal, vegetable, or mineral. The mineral sources may conveniently be grouped as non-metallic, metallic, rocks, and soils; the vegetable and animal by natural groups. But the matter and energy seized from nature are mere raw materials, as yet unfitted for application to the maintenance of the society. From this state, in which they may be termed potential products, they must be developed into that of ultimate products. And a little consideration will show that this process of development has generally three stages,—the first, of exploitation, including agriculture, mining, engineering, &c.; the second, of manufacture; the third, of movement by the agencies of transport and exchange to the place of ultimate application to the wants of the society—protection, alimentation, nervous stimulus, &c. These propositions are exhibited and somewhat extended in Table B 1.*

§ 15. In complex societies, however, a large proportion of raw materials has to be converted into apparatus for service in exploitation, manufacture, and transport; these may be termed mediate products. We have now the main principles of an exhaustive classification of all products whatsoever; thus—

α. *Potential Products.*
    See Table B 1.
β. *Mediate Products*, used in—
    1. Exploitation.
    2. Manufacture.
    3. Movement.
        (*a*) Transport.
        (*b*) Trade.
γ. *Ultimate Products.*†

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* This table is essentially borrowed from Tait and Balfour Stewart. See Balfour Stewart, "Elementary Treatise on Heat."

† The details of the above classification would involve the printing of a con-

§ 16. A farther large proportion of energy and matter is prematurely dissipated and disintegrated by various agencies, and at various stages of development, and thus never becomes used at all. Such premature dissipation is termed loss, and of course needs to be balanced against the gain recorded in the two preceding tables. The details arrange themselves as follows :—

Loss
- 1. Of raw materials
- 2. In exploitation
- 3. In manufacture
- 4. In transport
- 5. In exchange
- 6. Of ultimate products
- 7. In remedial effort

by
- 1. Physical agencies, *e.g.*,
  - Avalanche.
  - Earthquake.
  - Volcano.
  - Flood.
  - Storm, &c.
- 2. Biological agencies, *e.g.*,
  - Insects.
  - Fungi, &c.
- 3. Social agencies, *e.g.*,
  - Crime.
  - War.
  - Folly, &c.

§ 17. The second axiom—that a society consists of living organisms—leads us to the classification of their statistics. These arrange themselves in a way very analogous to that used for the statistics of territory (see p. 305, and Tables A I., II., III.) as follows :—

C. *Organisms composing society.*

I. Number at given time.
- 1. Surviving since last unit time.
- 2. Added since last unit time.
  - (*a*) By birth.
  - (*b*) By immigration.

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siderable number of minor tables, and are therefore omitted, as tending to exceed the limits and divert attention from the main purpose of the present paper.

II. Quality at given time,
  1. *Biological.*
    (*a*) Structural.
      α. Ethnological.
        (Race, aspect, &c.).
      β. Anthropometric.
        (Size, weight, &c.).
    (*b*) Functional.
      α. Efficiency of non-cerebral functions.
      β. Efficiency of cerebral functions (*Psychological*).
    (*c*) Distributional.
  2 *Social.*
    (*a*) Mutual relations.

III. Decrease since last unit time.
  1. By death.
  2. By emigration, &c.

§ 18. Since the organisms composing the society have by our first axiom certain time-relations, since by our third axiom they seize upon the matter and energy of nature, a new idea comes in, that of their occupations. In a complex society like the human, more time-relations or occupations are to be observed than those which concern the direct utilisation of nature. By the aid of these considerations and of the preceding tables, the occupations arrange themselves as follows:—

I. Operations on matter and energy, *i.e.*, concerned in
  1. Exploitation.
  2. Manufacture.
  3. Movement.
    (*a*) Transport.
    (*b*) Trade.

II. Operations on organisms composing given society.
  1. Service of non-cerebral functions.
    (*a*) Menial, domestic.
  2. Service of cerebral functions.
    (*a*) Æsthetic, intellectual, moral.
  3. Service of co-ordination.

III. (For this third class no completely satisfactory term exists. Its scope and limits are, however, as will afterwards be seen, none the less definite.)

1. Unemployed.
   (By reason of youth, misadventure, refusal, &c.).
2. Disabled.
   (By disease, defect, age, &c.).
3. Destructive.
   (War, crime, &c.).
4. Remedial.
   (Of disaster, disablement, destruction, &c.

§ 19. Knowing now the number and quality of the members of the society, and their respective occupations, and considering that they apply the resources of nature to the satisfaction of their wants, the manner in which these are divided—in other words the partition of products, comes next to be classified. This partition, it must be observed, may be either of territory of services of potential, mediate, or ultimate products, or of tokens or claims for these.

These facts may be thus tabulated :—

I. Mediate partition to classes A, B, C (and to members of various occupations contained in these).

1. Of claims (currency, &c.).
2. Of potential products.
3. Of mediate products.

II. Ultimate partition to A, B, C.

1. Of territory.
2. Of ultimate products.
3. Of services.

In some cases the partition is *nil;* that is to say, the products, territory, &c., are held in common.

§ 20. The partition of products to the members of the society being now disposed of, there next comes to be considered the mode of their consumption or use, for which a separate but similar set of tables is therefore provided.

§ 21. Finally, since the members of society are modified (1) in accordance with their modes of life or occupations, and (2) by their food and other material circumstances, since, in biological language, the organism is modified by its environment,* it is now necessary to inquire as to the results of the given occupations, and the given partition and use to the members following these. The biologist has accumulated a considerable body of knowledge respecting these results among animals, but comparatively little is known of human society in this respect. The foundation of an exhaustive knowledge of these results has, however, long ago been laid by the labours of the physician, the hygienist, and in a less degree by those of the educationist and philanthropist.

§ 22. These, then, are the primary tables, and we are now in a position to inquire how far our task of classifying the whole body of social statistics has been successful.

The scheme is scientific throughout—in accordance with the known truths of physical and biological science—is capable on the one hand of complete specialisation by the aid of minor tables, into the most trivial details of common life, and on the other, of generalisation into a colossal balance-sheet. Its systematic and generalised character appears clearly from a survey of the whole sheet of tables. It will be observed in the first place that the successive sets of tables, three each, may be read in horizontal rows, thus—Territory, Production, Organisms, Occupations, Partition, Use, Result. Secondly, that these sets of tables are related to each other: Organisms being treated on the same plan as Territory; the tables of Occupations being derived largely from those of Production, and the tables of Partition, Use, and Result, being in such close relation to those of Occupations that the ruling of each of the latter is exactly copied in all the four lower series; while the third, and by far the most important general view is obtained by looking at the left hand and middle vertical series (at least as far down as Occupations inclusive, and in some respects all the way), as entries on the debtor side of the balance-sheet, and similarly at the right hand vertical series as entries on the creditor side. Again, the scheme is universal in application—the tables will serve equally well for arranging our knowledge concerning any society—animal or human, civilised or savage:—for savage and animal societies, some columns here and there of course simply remaining blank. It is extremely simple, too, of understanding, and may, therefore, on all these grounds, satisfying as it does all the desiderata of a classification, legitimately claim a trial of convenience in use. In so far as the author's own studies have extended, it has proved eminently serviceable and suggestive; and, moreover, if it be admitted to be a better classification than its predecessors, it is entitled provisionally to supersede them for working purposes, according to the universal practice of the preliminary sciences, even although itself open to criticism.

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* This might, perhaps, more conveniently have been stated as a separate axiom.

§ 23. Such, then, being the classification in its most general and abstract form, its completion—a task even more than that of any of the preliminary sciences—needing innumerable lifetimes broad and long, would require subclassification into the minutest details of social life and the filling up all the major and minor tables for each given society, with the facts of which so many are already gathered into economic and statistical libraries, and so many are being periodically collected, but of which perhaps even more await investigators, and the notation of all these by all the resources of graphic statistics. Thus, with the comparison, too, of each record with those of other communities and of antecedent times—in other words the comparison of statistics with statistics, and history with history, it is hard to speculate how vast would be the outcome of elucidated laws.*

But while this complete application is not within our reach, it must not be supposed that no application is or can be made to practice, nor that the present is a mere untested scheme. On the contrary, a very considerable number of volumes of actual statistics, journals of societies, census returns, and works on special subjects, have been gone through, without the discovery of any facts relating to any given society which could not be immediately referred to their places on the tables, while the facts relating to relations between different societies arranged themselves conveniently as links between their respective sets of tables.†

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* It is interesting to compare these with the in many respects similar tables employed by Mr Spencer. See his "Descriptive Sociology."

† The reader may conveniently verify this statement by running through any such book, say a number of the Journal of the Statistical Society, or a

§ 24. Again, these tables, as the reader must already have noticed, embody much more than a mere classification for statistics in the narrower sense, and attempt nothing short of an organisation of the whole facts presented by the social sciences into a more definite and coherent body of knowledge than they have formed heretofore. The first series of tables, those of Territory, is intended to include the facts of political geography, while the second series is still more comprehensive. Its first table, that of Energy and Matter, includes the subjects commonly termed economic physics, economic geology, economic botany, and zoology, of which there is a large, but inco-ordinated literature. *

The table (B II.) entitled Development of Products, generalises a classification of the facts and processes of technology in the widest sense, including all the arts, coarse and fine, together with the processes of transport and exchange which the products undergo; the developmental history of any given product (which is in many respects analogous to that of an organism), being written across the table from left to right. The minor tables, as yet unpublished, of which the most important is outlined at page 306, contain a classification of all material products, potential, mediate, and ultimate. And it must not be supposed that these are mere *à priori* constructions, inapplicable to practice, the table of Development having really been worked out with a constant reference to the contents of technological encyclopædias (of which the present arrangement is usually merely alphabetic), while the minor tables are the result of many weeks' continuous attempt to classify the multitudinous contents of the last Paris Exposition, and of various smaller previous and subsequent museums of production.

In like manner the three tables devoted to the organisms com-

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copy of the Proceedings of Section F. of the British Association. At most he will only occasionally have a temporary difficulty in finding where to assign any subject, and this merely for want of the minor tables.

* The names of these subjects are unsatisfactory, since scientific physics, geology, and biology have no economic aspects at all. The biologist, for instance, divides his subject into morphology, physiology, distribution, and ætiology, and finds no place for economic considerations. These subjects are really sociological ones, and should therefore be termed respectively physical economics, geological economics, botanical and zoological economics. The change is no mere verbal one, but involves a radical alteration of the point of view and mode of treatment, and indeed demands the handing over of these subjects to other cultivators.

posing society generalise the results of the daily labours of the Registrar of births, deaths, and marriages, with those of the periodic census, and there again with anthropological and educational statistics, while the three tables immediately following offer a solution of two long outstanding and highly important problems,—first, that of the classification of occupations;* and second, that of the nature of productive and unproductive labour.

Lastly, the tables of Production, Partition, and Use aim respectively at including the facts of the usual divisions of political economy—the production, distribution, and consumption of wealth; while the last—those of Result—cover, as before stated, a large but incomplete and unsystematised body of knowledge accumulated by biologists, physicians, educationists, and philanthropists, and relating to the reaction of the environment upon the organisms composing the society.

§ 25. If, therefore, it has been admitted that the series of tables are placed in order and organised into a whole, it becomes evident that the subjects just enumerated, viz., the facts of political geography, of physical, geological, botanical, and zoological economics, of technology and the fine arts, of anthropology, of demography, and of political economy have similarly been placed in order and organised into a whole. This whole body of facts treated statistically and historically, and the generalisations obtained from them, together with an account of intersocial relations, would constitute a complete account of the society, or group of societies.

§ 26. While it is evident that in our ascending progress from the preliminary sciences no shock has been felt, and no difficulty found, in the successive assimilation of the facts of political geography, physical and biological economics, technology and demography, a vast hiatus becomes evident on our approach to political economy. For here we find not a definite record of observed phenomena aiming at exhaustiveness, together with the generalisations obtained therefrom, but a multitude of contending systems, bearing sometimes geographical names, as British school, Italian school, sometimes named after their founders, or sometimes designated by some prominent aspect of their doctrine, as Socialism, Communism, &c., each claiming orthodoxy and opposing its contemporaries obliquely or diametrically. This state of things, fortunately unique in science, makes desirable an exhaustive study and classification of all these rival systems; but within our present limits it is only possible to attempt a brief glance at their main points of difference and of agreement.

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* See the very interesting alphabetic list of occupations in the London Directory, and the discussions as to classification in the Report of the United States Census, 1870, and Report of Census of Scotland, 1871, where detailed classifications are also given.

First, then, they differ as to whether the subject be a science at all, some authors regarding it as an art, others as something distinct from both. Restricting ourselves henceforth to the great majority of schools which hold the first-mentioned opinion, we find them agree in the extensive adulteration of their scientific matter with irrelevant discussions, which are occasionally of a theological nature, but much oftener metaphysical, and most frequently practical—a peculiarity which helps to explain the low esteem into which the subject has been steadily falling during the last generation, among theologians and metaphysicians, practical and scientific men alike. Such digressions are, however, common to the infancy of every department of knowledge, and must not, therefore, be too hardly dwelt upon. A more serious difficulty lies in the want of unanimity among the various schools as to the position of their subject with respect to other sciences, some spending no little labour in an endeavour to isolate it from other branches of knowledge altogether, while others claim it to be a logical science, others a mathematical, others a physical, others a biological, others a psychological, others a sociological, others an ethical science, while some hold it to belong partly to one and partly to another. In other words, the subject has been referred to every possible position in the classification of the sciences with the exceptions of astronomy, chemistry, and geology. And while it must be admitted that the teachers of these various systems are usually admirable as logicians, and that many also freely use mathematical reasonings and illustrations, they do not apply their knowledge to any great extent in the quantitative study of phenomena nor to the analysis of the facts recorded by statisticians. And again, although political economy is said to deal largely with material things, and largely with organised beings, there is probably no department of modern literature, not even poetry or romance, so little leavened by the recent advances of our knowledge of the laws of matter and of life. To judge from their writings the economists would seem to be unconscious of the very existence of such doctrines as those of the conservation and dissipation of energy, of evolution, and the like, and of the evident fact that the students of the physical and biological sciences can hardly much longer delay a combined invasion of their territory.* Moreover, although archaic psychological conceptions—frequently, of course, of fundamental importance—are tenaciously retained, the economist usually holds aloof from considering the important constructive sociological efforts already made from the side of the preliminary sciences, while the only ethical allusion to be found in many a lengthy economic treatise is a contemptuous dismissal of "sentiment."

Passing lightly over these disputes as to whether the subject is to be treated purely by deduction, or by induction, or by both, and evading the interminable discussions about the definition of terms, since they compel the abandonment of most of these altogether, we are arrested by the most serious discrepancy of all—that relating to the very scope and nature of political economy. We find that some schools narrow the subject to industry alone, others to government, others to value, others to exchange, so that it has actually been proposed within recent years to confine the title to the study of the commercial phenomena of the present industrial period in England, that is to say in the language of our tables, to little more than certain of the phenomena of movement at a given time in one society; while even many of those systems which take a wider view and seek to investigate production, partition, and use are often justly reproached with ignoring the organisms composing the society altogether, or at the very least with too scanty attention to the all-important results of production, occupation, partition, and use upon these organisms, while they are prone to state their generalisations of the local and the temporary as absolute laws. And, finally, we find that many of these widest systems concern themselves little with actual periodic detailed and quantitative observation of current phenomena, and still less with historical studies, that is to say, with what we saw at the outset to be the two real aspects of the subject; while even the schools which pay most attention to statistics and to history are still far from basing their labours on the foundation of the preliminary sciences.

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* See Presidential Addresses to Sections A, F, G of the British Association, York, 1881.

§ 27. But is not the preceding criticism altogether too completely destructive? In no wise, for it is only levelled against the economic systems as systems, each with pretensions to intellectual completeness. But when the claim to system and completeness is withdrawn all at once become entitled to a respectful examination. Valuable materials have been collected, constructive of scientific economics. Statistical and historical inquiry have long been in active progress; wider and wider conceptions of the range and place of social science are daily gaining ground, while those very schools which we have just been criticising for their narrowness of observation have in some respects all the more clearly focussed the subjects within their range, and have traced for us many of the most important phenomena of industry or commerce, of finance or government. And if our present limits had admitted of any detailed criticism, it would have been easy to show a certain degree of real progress on the part of many recent political economists towards the acceptance of scientific methods and ideas.[*]

And the real claim of the system outlined in the preceding pages lies not in its newness, for it indeed contains probably no new ideas at all, but in its serving as far as consistent with truth to represent the doctrine of each, and to harmonise the labours of all the schools. Thus, for instance, it is one of the most marked advantages of the tables that it would be easy to monograph on this principle a city or a village, a single household or even an individual, as well as a nation, to compare these facts of personal and domestic economy among each other, and to generalise bodies of these; yet this is simply a return to the conception from which political economy arose and departed, that of the study of household management and law.[†] Again, the postulation of the preliminary sciences, the idea of territory yielding matter and energy which manufactures and commerce can only develop into ultimate products; these, with the classification of occupations, are the ideas of the leader of the economic Renaissance, the physician and physiologist De Quesnay, although the more advanced science of our day enables us to avoid the errors into which he fell: so, too, the larger view of industry and commerce, the detailed examination of products and processes, of mediate and ultimate partition and the like, the statistical, historical, and comparative inquiries, and, above all, the treatment of economic questions as forming not a totally isolated department of knowledge, but an integral part of the general study of man and of society, form the very essence of the "Wealth of Nations."

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[*] Ex. gr. Marshall, "Economics of Industry," London, 1880. Guyot, "La Science Economique," Paris, 1881.

[†] Πολιτεια, *οικια*, *οἰκος*, *νομος*.

It would be easy to multiply examples, to show how complete and detailed a harmony of the matter and spirit of the various schools, statistical as well as economical, the scheme affords us, and how it solves so many apparently difficult and long-disputed problems; how, for instance, the fundamental conception of organisms utilising the matter and energy of nature clears up such time-honoured disputes as those concerning the nature of interest and of intrinsic value, or how light is thrown upon such phenomena as those of competition and co-operation by the biological conceptions of struggle for existence, of physiological differentiation, of polymorphism, and of functional change. But space does not permit any further development of the scientific aspects of the subject, and it is necessary at once to proceed to the investigation of practical economics.

§ 28. Since the organisms composing society are largely occupied in utilising matter and energy; since, moreover, every action and every movement involves some disintegration and dissipation of energy—produces, that is to say, an economic result—it is evident that an exhaustive study of practical economics would involve a quantitative record and classification of every action going on in the society. Such exhaustiveness is, of course, impossible; but without going to any such extreme it is desirable and interesting to make some attempt. Much can, of course, be done by observing and classifying the activities we see going on around us; but as a convenient periodic record in which most of the more important actions going on in the community find at least occasional mention is furnished by the daily newspaper, it will suffice for the present to take it as an example, and refer each item of news to its place in our classification. Thus, taking a few at random: *—

Subject.	Society.	Subject of Table.	Minor Table.
1. Irish Land Bill.	Ireland.	Ultimate Partition.	Territory.
2. Opening of Leith Dock.	Scotland.	Mediate Products.	Movement (Transport).
3. Funeral of ——	England.	Organisms. Loss.	Death.
4. Amount of Revenue.	Britain.	Mediate Partition.	Nil, Co-ordination, &c.
5. Wreck of Shetland Fishing Fleet.	Scotland.	(*a*) Products. Loss. (*b*) Organisms. Loss.	Exploitation, by Storm. Death.
6. American Wheat Crop.	United States. Canada.	Energy.	Exploitation. Veg. Food.
7. Daring Murder.	England.	(*a*) Occupations. C. (*b*) Organisms. Loss.	Destructive Crime. Death.
8. Opening of New Hospital.	England.	Ultimate Partition of Ult. Prod. and Services.	Occupations C. Disabled.

But such an arrangement of the actual passing economic actions, though instructive, is quite insufficient. As from our system of astronomical knowledge it is necessary to deduce the art of navigation, so from our system of sociological knowledge we must derive the art of conduct. This want has been thoroughly felt by all the different economic schools—so thoroughly indeed, as to lead, as was before remarked, to the frequent obscuring of the scientific object altogether. A classification and criticism of the practical projects of the various schools should here find place, if space permitted. This, however, may for the time being be dispensed with, since we find complete absence of unanimity, individualism being opposed by socialism, free-trade by protectionism, and so on. Thus, as we have as yet no criterion of morals or expediency, but simply our knowledge of the preliminary sciences, and since it is not the practice of the preliminary sciences to accept mere authority, such opposing schools must for the time being be considered as neutralising each other.

What, then, is to guide us in the construction of rules of practical economics? Shall we rest contented with such a survey of practical action as our classified newspaper affords us, and do as others do? This is an important principle of action, as custom and fashion bear witness, yet hardly needs detailed exposure of its unscientific character or of the consequences into which it might lead. Shall we do, then, as others advise? Much advice certainly is current from newspapers, economic schools, and other quarters; but such authority, however often good, has already been dismissed. We are thus thrown back upon our scientific knowledge. Why should we not act upon that? Since nature yields matter and energy, let us utilise nature. Since organisms struggle for existence, let us compete; since, too, they join in united action, let us co-operate. This seems more hopeful, and might be largely developed to furnish practical axioms, tolerably coincident on the whole with the majority of existing customs and precepts. Practical rules of conduct may be made corresponding, for instance, to the table of energy, counselling us to utilise tides, coal, timber, plants, and animals. Yet if these preceding scientific grounds be accepted as sufficient for these practical actions, consistency demands the similar utilisation of the organisms composing society—that is to say, of our fellow-men, as machines, food, &c.; courses, moreover, for which there exist in many societies abundant precedents, both of custom and of counsel. Competition, too, as might easily be shown, would lead us to similar courses of action, and so on with the rest. In short, then, the development of scientific knowledge into practical action is in many cases serviceable, yet here and there without warning leads us into a course where we find ourselves confronted by a difficulty of a new order—the moral.

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* With the limitation stated at page 311, *note* 2, the reader may continue this with any journal. See also author's paper, Brit. Ass. 1881, and "Nature," 29 Sept. 1881, for similar classification of anthropological and economic papers.

§ 29. How is it that every proposed course of action has thus led us into difficulties? Because we are seeking rules of action without having defined any aim of action. As we required axioms for scientific economics, so now we require postulates for action, and the latter are readily derivable from the former; thus from our first axiom that the society exists within limits of space and time, the corresponding postulate is evident—let the society exist within limits of space and time, while from the second, third, and fourth axioms the respective postulates arise—(2) let the society consist of living organisms, (3) let them seize the matter and energy of surrounding nature, (4) let them apply this to the purposes of their life, and so on; for, as it was pointed out, that as our knowledge of the nature of societies in general and in particular progresses, new axioms would necessarily be added to the most general ones with which we started, so corresponding postulates for action would be derived from these, for in every art our code of action is the necessary complement of our scientific knowledge. This principle of practical conduct must not be mistaken for the principle last criticised, and which was seen to lead us into difficulties, that of acting upon any portion of scientific knowledge irrespective of its importance to society; this proposes the adaptation of our action to our whole knowledge of society, and the consequent infringement of no axiom, and recognises the necessary imperfection of such action in proportion as our knowledge is incomplete. This most highly abstract form of practical economics is capable of development into detail.

§ 30. But a higher order of considerations than the sociological came lately into view—the ethical. Reversing our usual order and beginning with the practical considerations, we recognise here as before a vast multiplicity of actions in course of actual performance in each society, termed good or bad, right or wrong, the application and definition of these terms differing somewhat in different societies and schools, custom and counsel too differing as before. An examination of these actions to which moral importance has been assigned, shows that at least many, for instance crime, remedial effort, &c., have already been included in our survey of practical economics, while a reconsideration of our economic phenomena shows that moral significance is constantly attached to common acts, say of commerce or husbandry. The interesting detailed examination of the economic aspects of actions commonly termed moral, and of the moral aspects of actions commonly termed economic, which must be left to the reader, leads to the conclusion that at least the majority of the actions going on in the society (probably indeed all) possess both aspects. Without going so far, if it be granted that certain practical actions have both economic and ethical aspects, it follows that in these given respects both moral and economic action must coincide. For if the action based upon economic science do not coincide with the action based upon ethical science (assuming such science to exist), it follows that the two sciences of sociology and ethics are not in unity; and inversely, if this denial of the unity of science be not made, economic action must harmonise and coincide with moral action.

This coincidence of practical economics with practical ethics, of economy with morality, being implied in such common conceptions as those of conduct, duty, and the like, and indeed in almost every application of these terms, and having been often pointed out by philosophers and moralists should need little illustration, were it not that the introduction into practice of ethical conceptions, for various reasons of greater or less cogency, has been proclaimed irrelevant by not a few political economists, of whom some would indeed almost seem to have believed in a veritable antagonism of these two aspects of conduct. Such views of ethics and economics are harmonious with that want of relation to the preliminary sciences referred to in § 26 as characteristic of such economists.

Such a comparison of the two aspects of proposed actions instead of being avoided should indeed invariably be adopted. Since we saw that economic action should be based upon scientific knowledge and that not fragmentary but complete, and since our sociological knowledge is dangerously incomplete, while action is inevitable, the utility of the moral check already referred to in § 28 becomes apparent. When the counsel of economics and of morals coincide the action may be regarded as ratified and its grounds as verified, while a discord between the two must similarly be regarded as indicating that the proposed course of action whether ethical or economic must be in error. Though the course of action proposed on ethical grounds may sometimes be even more liable to error than that proposed on those of our as yet so imperfect economic knowledge, yet cases frequently occur more or less analogous to those taken for example in § 28 in which the former course is to be adopted, its accompanying emotional state then serving as a help not as a hindrance.

§ 31. Having thus reached the ethical platform we find a new series of ethical systems inviting study and criticism, but a single instance chosen almost at hazard must suffice. If practical economic action coincides with ethical action, our most general principle of economic action, which we have seen to be "act upon postulates," is also a general principle of ethical action. But this principle is essentially similar to the most abstract law of the Intellectualist system of ethics,—the Categorical Imperative of Kant,—especially when developed into its individualistic and concrete forms.

But such comparisons of the various ethical systems, however interesting, would lead into ground for unnecessary controversy. The object of the present paper, probably the first which has attempted to organise the whole body of our recorded social knowledge into a form presentable to the cultivators of the preliminary sciences, will have been sufficiently gained if the unity and continuity of these, with the social and moral sciences, has been made in some respects clearer than heretofore, and if the mode of treatment and arrangement of the facts of social science therein proposed be admitted as satisfactory and serviceable.

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CLASSIFICATION OF STAT

A

(Space Relations.) TERRITORY OF SOCIETY.—I. QUANTITATIVE.

	Previously Existent.	INCREASE.				
		By Social Agency.				By Geologic Agency.
		Discovery.	Conquest.	Purchase.	Reclamation, &c.	
LAND. WATER.						

TERRITORY OF SOCIETY.—II. QUALITA

	UNUSED.	USED.	
		Unspecialised for	
		Functions.	
LAND. WATER.			

B

PRODUCTION.—I. (*a.*) SOURCES OF ENERGY IN TERRITORY.

Primitive Chem. Affinity.	Earth's Internal Heat.	Earth's Rotation.	SOLAR RADIATION.				
Potential.	Kinetic.	Kinetic.	Kinetic.	Potential.			
				Earth's Crust.	Organisms.		
					Surrounding Society.		Composing Society.
					Plants.	Animals.	
A. Elements (uncombined).	*A.* Hotsprings. *B.* Volcanoes.	*A.* Tides.	*A.* Sunshine. *B.* Falling water. *C.* Wind.	(*A.* Food) *B.* Fuel— 1. Coal. 2. Lignite peat. 3. Oil and gas springs. *C.* Soil (deoxidised matter of).	*A.* Food. *B.* Fuel.	*A.* Food. *B.* Fuel. *C.* Machines.	*A.* Food. *B.* Fuel. *C.* Machines.

(*β.*) SOURCES OF MATTER USED FOR THE SAKE OF OTHER PROPERTIES

(Physical—Chemical—Physiological).

Production. II. DEVELOPMENT OF ULTIMATE PROD

	Potential Products. (Raw Material.)	Exploitation.	Manufacture.	Mov
a. ENERGY.	Tides, Sunshine, Falling water, Wind, Coal and peat, Plants, Animals, &c.	Agriculture, Fishery, Mining, Engineering, &c.		
	Waste products.			
β. MATTER.	Non-metals, Metals, Rocks and soils,			

IFICATION OF STATISTICS.

TERRITORY OF SOCIETY.—II. QUALITATIVE.

	UNUSED.	USED.	
		Unspecialised for Functions.	Specialised for Functions.

TERRITORY OF SOCIETY.—III. DECREASE.

	BY SOCIAL AGENCY.	BY GEOLOGIC AGENCY.
LAND.		
WATER.		

n. II. DEVELOPMENT OF ULTIMATE PRODUCTS.

	Potential Products. (Raw Material.)	Exploitation.	Manufacture.	Movement.	Ultimate Products.
GY.	Tides, Sunshine, Falling water, Wind, Coal and peat, Plants, Animals, &c.	Agriculture, Fishery, Mining, Engineering, &c.		Transportation and Exchange.	*e.g.* Protective and Supporting. Locomotive. Alimentary. Æsthetic.
	Waste products.				
ER.	Non-metals, Metals, Rocks and soils,				Destructive.

Production. III. LOSS. Premature Dissipation of Energy and Disintegration of Matter.

Agency.	In Raw Materials.	In Exploitation.	In Manufacture.	In Transport.	In Exchange.	In ultimate Products.	In Remedial Effort.
A. Physical, *e.g.*, Avalanche, Volcano, Earthquake, Flood, Storm.							
B. Biological, *e.g.*, Insects, Fungi.							
C. Social. *e.g.*, Crime. War. Folly.							

Mineral.				Vegetable.	Animal.
Non-Metals.	Ores.	Rocks.	Soils.	Natural Orders.	Natural Orders.

C

ORGANISMS COMPOSING SOCIETY.—I. QUANTITATIVE.

Sex.	Previously Existent.	Increase.	
		Immigrants.	Births.

OCCUPATIONS I.

(Time Relations.)

Operations on Matter and Energy.
(Indirect services to members of Society.)

Sex.	Energy and Matter.	Exploitation.	Manufacture.	Transport.	Exchange.
	See Table B II. Development of Ultimate Products.				

MEDIATE PARTITION *NIL* AND TO CLASS I.

	Nil (Common to all Classes).				
Claims (Currency, &c.) Potential Products. Mediate Products.					

ULTIMATE PARTITION *NIL* AND TO CLASS I.

	Plants, Animals, &c.			
	Waste products.			

ORGANISMS COMPOSING SOCIETY.—II. QUAL

Biological.							PSY LOG
Distribution.	Structure.				Function. (Efficiency.)		
	Ethnological.		Anthropometric.		Non-Cerebral.	Cer	
	Race.	Aspect.	Size.	Weight, &c.			

OCCUPATIONS II.

Operat
(Direct servic

Service of Non-Cerebral Functions.		Service of Cerebral Functions.		
Menial, &c.	Domestic.	Æsthetic.	Intellectual.	Moral.

MEDIATE PARTITION TO CLASS II.

ULTIMATE PARTITION TO CLASS I

Plants, Animals, &c.				Remedial.
Waste products.				

ORGANISMS COMPOSING SOCIETY.—II. QUALITATIVE.

BIOLOGICAL.						PSYCHOLOGICAL.	SOCIAL.
UTION.	STRUCTURE.				FUNCTION. (Efficiency.)		MUTUAL RELATIONS.
	Ethnological.		Anthropometric.		Non-Cerebral.	Cerebral.	
	Race.	Aspect.	Size.	Weight, &c.			

ORGANISMS COMPOSING SOCIETY.—III. DECREASE.

EMIGRANTS.	DEATHS.

OCCUPATIONS II.

Operations on Organisms.
(Direct services to members of Society.)

ce of Non-Cerebral Functions.		Service of Cerebral Functions.			Service of Co-ordination.
&c.	Domestic.	Æsthetic.	Intellectual.	Moral.	Government, &c.

OCCUPATIONS III.

UNEMPLOYED.			DISABLED.			DESTRUCTIVE.		REMEDIAL OF		
Youth.	Misadventure.	Refusal.	Disease.	Defect.	Age.	War.	Crime.	Disaster.	Disablement.	Destruction.

MEDIATE PARTITION TO CLASS II.

MEDIATE PARTITION TO CLASS III.

ULTIMATE PARTITION TO CLASS II.

ULTIMATE PARTITION TO CLASS III.

D

MEDIATE PARTITION *NIL* AND TO CLASS I.

	Nil (Common to all Classes).				
Claims (Currency, &c.) Potential Products. Mediate Products.					

MEDIATE PARTITION TO CLASS II.

ULTIMATE PARTITION *NIL* AND TO CLASS I.

Territory. Ultimate Products. Services.					

ULTIMATE PARTITION TO CLASS

USE IN COMMON, AND BY CLASS I.

USE BY CLASS II.

RESULT TO COMMUNITY; AND CLASS I.

RESULT—CLASS II.

MEDIATE PARTITION TO CLASS II.

ULTIMATE PARTITION TO CLASS II.

USE BY CLASS II.

RESULT—CLASS II.

MEDIATE PARTITION TO CLASS III.

ULTIMATE PARTITION TO CLASS III.

USE BY CLASS III.

RESULT—CLASS III.
